The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Field programs and research work units of the Station are maintained in:

- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
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United States
Department of
Agriculture

Forest Service

**Intermountain
Forest and Range
Experiment Station**

General Technical
Report INT-119

September 1981

An Annotated Bibliography of Wind Velocity Literature Relating to Forest Fire Behavior Studies

RESEARCH SUMMARY

This bibliography was developed primarily for fire behavior research; however, the information should also be useful in support of other forest protection studies. Most of the references deal with surface wind velocities acting within the local scale of most forest fires. Subjects not covered include instrumentation, installation, observational techniques, forecasting, and fire-induced winds such as fire whirls and indraft flow. All foreign references given are either in English or have English translations. Some references were obtained through a WESTFORNET literature search. With one exception, the period covered is from 1940 through 1979.

THE AUTHOR

ROBERT G. BAUGHMAN holds B.S. and M.S. degrees in meteorology and climatology from the University of Washington, Seattle. From 1954 to 1958 he was engaged in arctic research with the U.S. Army Corps of Engineers. Since joining the Forest Service in 1958, he has held the position of research meteorologist at the Northern Forest Fire Laboratory and has been involved in research on thunderstorms, lightning, weather modifications, and forest meteorology.

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**Compiled by
Robert G. Baughman**

BIBLIOGRAPHY

1. Albini, F. A., and R. G. Baughman.
1979. Estimating windspeeds for predicting wildland fire behavior. USDA For. Serv. Res. Pap. INT-221, 12 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

A means of estimating the ratio of the mean windspeed acting at flame height to the windspeed at 20 feet above the vegetation cover is given. A model for relating windspeed within a uniform forest canopy to the windspeed above the canopy is presented. Important variables in the model include stand height, crown closure, foliar surface-to-volume ratio, and crown bulk density.

2. Alexander, A. J., and C. F. Coles.
1971. A theoretical study of wind flow over hills. *In* Proc. 3rd Int. Congr. on Wind Loads on Buildings and Structures, Vol. 1, paper 10. p. 95-103.

The equations of motion are solved numerically to compute the flow over a hill of arbitrary shape. Examples are presented for two hill profiles and two initial velocity profiles. Results indicate the hill influence does not extend beyond four times its height and that a very rapid increase in velocity to a maximum value occurs at the brow of the hill.

3. Alexander, Robert R.
1964. Minimizing windfall around clear cuttings in spruce-fir forests. For. Sci. 10 (2):130-142.

A study of windfalls in clearcut areas identified situations and conditions where windthrow hazards were above and below average. Guidelines to minimize windfall are given.

4. Allen, L. H., Jr.
1968. Turbulence and wind speed spectra within a Japanese larch plantation. J. Appl. Meteorol. 7(1):73-78.

A log-profile analysis yielded a wide range of values for the roughness length and the zero-plane displacement height. Large eddies penetrated deeper in the forest after needle fall and during high winds. Most of the variation in windspeed was associated with gusts of about 100-meter wave length. Power spectra showed considerable modification due to tree spacing in the most dense portion of the canopy.

5. Anderson, Gerald E.
1971. Mesoscale influence on wind fields. J. Appl. Meteorol. 10(3):377-386.

Simple analyses based on the divergence equation permit calculation of wind fields that appear more realistic than wind fields produced by other objective analyses. The analyses, which are computationally simple, provide an objective procedure for real-time, forecast, or hypothetical cases.

6. Arya, S. P. S., and M. S. Shipman.
1979. A model study of boundary layer flow and diffusion over a ridge. Fourth Symp. on Turbulence, Diffusion, and Air Pollution, Meteor...
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The flow of air over a lo...
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um was absorbed mostly in the upper layers of the canopy. An analysis showed that the aerodynamic features of the upper layers of the canopy were characterized by friction velocity and height of the zero-plane displacement.

9. Baines, G. B. K.
1972. Turbulence in a wheat crop. Agric. Meteorol. 10(1/2):93-105.
Wind velocity measurements were made at several heights (from 8 to 94 cm) within the crop stand. Plant-generated turbulence and the dissipation of kinetic energy were studied. The Strouhal number was used to predict the scale of turbulence generated by leaves and stems.

10. Ball, Joseph A.
1975. Concept for a high-resolution toposcale wind model to estimate surface wind in a complex terrain. 12 p. Mission Res. Corp., Santa Barbara, Calif.
Concepts are given for a numerical model to estimate winds in mountainous terrain. Required are topographic data and observations or predictions of surface temperature and wind at several locations or an estimated general surface wind and temperature from a sounding near the modeled area.

11. Barad, Morton L.
1961. Low-altitude jet streams. Sci. Am. 205(2): 120-131.
A popular discussion of the general mechanics of the low-level jetstream that often produces strong winds at night between 800 and 2,000 feet above the ground. The winds appear to play a role in the birth of storms.

12. Barad, Morton L.
1963. Examination of a wind profile proposed by Swinbank. J. Appl. Meteorol. 2(6):747-754.
A theoretical model of windspeed profiles in the lower boundary layer during conditions of nonneutral temperature stratification was examined. The Swinbank derivation depends upon an assumption that the Monin-Obukhov length is constant. Analyses of observations show this is not so. It is concluded that the Swinbank hypothesis is not verified by data.

13. Barr, Sumner.
1971. A modeling study of several aspects of canopy flow. Mon. Weather Rev. 99(6):485-493.
The problem of steady flow in a horizontally infinite canopy under neutral thermal stratification is treated theoretically. The resulting model is then used as a boundary condition for a nonlinear numerical model designed to study transition regions near the leading and trailing edges of a canopy. The model shows a wave effect downstream from a leading edge and a tendency for splitting of the flow near a windward edge.

14. Barrows, J. S.
1951. Fire behavior in the Northern Rocky Mountain Forests. USDA For. Serv. Stn. Pap. No. 29, 103 p. North. Rocky Mt. For. and Range Exp. Stn., Missoula, Mont.
A well illustrated and descriptive discussion of fire behavior including the effect of weather elements is presented. Wind velocity is discussed on pages 29-33. The Northern Rocky Mountain scale of wind velocity for use in estimating wind velocities is shown.

15. Baynton, Harold W., W. Gale Biggs, Harry L. Hamilton, Jr., Paul E. Sherr, and James J. B. Worth.
1965. Wind structure in and above a tropical forest. J. Appl. Meteorol. 4(6):670-675.
Winds were measured, up to a height of 200 feet, in and above a tropical rain forest in northern Columbia. Windspeeds below the canopy were only 1 to 5 percent of that measured 50 feet above the canopy. Wind directions below the canopy appear to be disorganized.

16. Bergen, James D.
1969. Cold air drainage on a forested mountain slope. J. Appl. Meteorol. 8(6):884-895.
An attempt was made to relate the volume and velocity of flow to the net radiation balance on a forested slope. The local mean windspeed varies as the square root of the temperature drop down the slope and the sine of the angle of the slope. The potential temperature drop down the hillside varies approximately as the two-thirds power of the estimated net radiation loss.

17. Bergen, James D.
1971. Vertical profiles of windspeed in a pine stand. For. Sci. 17(3):314-321.
Simultaneous measurements of windspeed were made at six heights extending to the top of a lodgepole pine stand. The windspeed profile expressed as a fraction of the friction velocity above the stand is invariant for a wide range of windspeeds above the canopy. The profiles show a minimum in the live crown and a subcanopy maximum.

18. Bergen, James D.
1974. The independence of the point-to-point variations in windspeed and temperature in a lodgepole pine stand. USDA For. Serv. Res. Note RM-258, 2 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.
The correlations between local variations in air temperature and windspeed were examined. The results indicate that the point-to-point deviations are independent. The independence of wind and temperature fields supports the use of averages of temperature and windspeed when applying energy balance techniques at the forest floor.

19. Bergen, James. D.
1974. Variation of windspeed with canopy cover within a lodgepole pine stand. USDA For. Serv. Res. Note RM-252, 4 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.
A linear correlation suggests independence between point-to-point variations in speed at any level and variation at canopy cover.

20. Bergen, James D.
1975. Air movement in a forest clearing as indicated by smoke drift. Agric. Meteorol. 15(2):165-179.
Cinematic observations were made of smoke drift in a clearing (10 by 50 cm) cut in an even-aged stand (average height 10 m) of lodgepole pine. Results indicate a continuous alteration between separated (rotor) and unseparated (through-flow) flow in fair agreement with the eddy shedding frequency of a flat plat in uniform flow. The vortex rotor appears to dominate the distribution and direction of the maximum windspeeds in the clearing.

21. Bergen, James D.

1975. An approximate analysis of the momentum balance for the airflow in a pine stand. *In* Heat and mass transfer in the biosphere, part 1. Transfer processes in the plant environment. p. 287-298. D. A. deVries and N. H. Afgan, eds. Scripta Book Co., Washington, D.C.

Estimates of velocity profiles, volume drag coefficient, and effective viscosity were obtained from windspeed and foliage distribution measurements. Results suggest that live branches are the characteristic drag element and that the effective viscosity has an appreciable dispersive component.

22. Bergen, James D.

1975. Windspeed distribution in an isolated forest clearing. Twelfth Agric. and For. Meteorol. Conf. [Tucson, Ariz., Apr. 14-16, 1975]. p. 45-46. Am. Meteorol. Soc.

Measurements made in an extended 28 by 49 meters clearing are compared to those made earlier in a 10 by 49 meters clearing. Higher windspeeds were measured in the larger clearing.

23. Bergen, James D.

1976. Air flow in forest canopies--a review of recent research in modeling the momentum balance. 47 p. Paper presented at the Fourth Natl. Conf. on Fire and Forest Meteorol. [St. Louis, Mo., Nov. 16-18]. [Abstract published in Proceedings.]

Presents an overview of the state-of-the-art in mathematical modeling of airflow in forest canopies. Three recent models are examined as divergent solutions to the modeling problem. None of the models correctly predicts the velocity maximum found in the subcanopy space in field and wind tunnel investigations. Apparently, there is currently no generally accepted model for the momentum balance of airflow in a forest canopy.

24. Bergen, James D.

1976. Some measurements of the adiabatic wind profile over a tall and irregular forest. Fourth Natl. Conf. on Fire and Forest Meteorol. [St. Louis, Mo., Nov. 16-18, 1976]. p. 116-121. USDA For. Serv. Gen. Tech. Rep. RM-32. Rocky Mt. For. and Range Exp. Stn., Fort Collins. Colo.

Results indicate: (1) an increase of roughness length with windspeed and (2) a general decrease in displacement thickness with speed.

25. Bergen, James D.

1976. Windspeed distribution in and near an isolated narrow forest clearing. Agric. Meteorol. 17(2): 111-133.

Windspeeds were measured on a three-dimension array in a 10 by 50 m clearing cut in a 10-m high lodgepole pine stand. The ratio of local windspeed to above canopy friction velocity is independent of the latter and stability. The flow shows extensive separation in the time average. The effect of the clearing extends more than five tree heights behind the clearing but is negligible upwind of the clearing. Minimum speeds occurred at the clearing center while maximum speeds occurred at subcanopy levels and above the tree edge of the clearing.

26. Bergen, James D.

1979. The windflow to the lee of a forest edge. Fourteenth Conf. on Agric. and For. Meteorol. [Minneapolis, Minn., Apr. 2-6, 1979]. p. 170-172.

A first-order model of airflow in forest clearings is presented. The model predicts some of the general features of observed airflow in a clearing; it should be useful in predicting air and soil temperature and snow diposition in clearings.

27. Berglund, Erwin R., and Richard J. Barney.

1977. Air temperature and wind profiles in an Alaskan lowland black spruce stand. USDA For. Serv. Res. Note PNW-305, 12 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Results indicate windspeeds measured 4.5 meters above an Alaskan black spruce stand are four times faster than those measured 0.5 meters above ground vegetation.

28. Berman, E. A., D. E. Steffen, G. Taylor, and D. Kringel.

1977. Numerical simulation of flow fields in rough terrain. *In* Joint Conf. on Applications of Air Pollution Meteorology. [Sponsored by the Am. Meteorol. Soc. and the Air Pollution Control Assoc., Salt Lake City, Utah, Nov. 29 to Dec. 2, 1977.] p. 204-208.

The theoretical basis and computational formalism of a wind model is presented. The model (WINDS) generates a nondivergent wind field during stable or neutral atmospheric conditions. The results of a case study in the Los Angeles area are given.

29. Berman, S.

1965. Estimating the longitudinal wind spectrum near the ground. Q. J. Royal Meteorol. Soc. 91(389):302-317.

Presents a graphical procedure for estimating the spectrum of the longitudinal wind component from height, mean windspeed, roughness length, and stability data. Observations suggest the spectrum is more variable in the lower frequency as compared with the higher frequencies. No systematic variation with height could be seen.

30. Bhumralkar, Chandrakant M.

1973. An observational and theoretical study of atmospheric flow over a heated island: Part Mon. Weather Rev. 1[illegible]

Part 1 is the [illegible]

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Mon. Weather Rev. 101(10):731-745.

In part 2, a general theoretical nonlinear model is presented that can simulate the reaction of the atmosphere to surface heating and friction. The model includes continuity equations that predict water vapor, cloud water, and liquid water. Results show that the larger the temperature excess of the heat source, the greater the intensity of the induced disturbance.

32. Blackadar, Alfred K.
1957. Boundary layer wind maxima and their significance for the growth of nocturnal inversions. Bull. Am. Meteorol. Soc. 38(5):283-290.

A sharp windspeed maximum frequently observed at night below 3,000 feet is explored in terms of a low-level jet. The wind maxima, usually at the top of the nocturnal temperature inversion, is supergeostrophic and associated with large values of wind shear at low levels. The supergeostrophic windspeeds suggest that inertia oscillation is induced when the constraint imposed by daytime mixing is released by the initiation of an inversion at about the time of sunset.

33. Blackadar, Alfred K.
1960. A survey of wind characteristics below 1500 feet. *In* Topics in engineering meteorology. Meteorol. Monogr. 4(22):3-11.

The survey includes work by Prandtl, Deacon, Monin, and Obukhov, and Ellison. Adiabatic and diabatic wind profiles are discussed. The vertical distribution of peak velocities is also discussed. A brief theory of the low-level jet wind is given.

34. Blackadar, Alfred K.
1976. Modeling the nocturnal boundary layer. Third Symp. on Atomospheric Turbulence, Diffusion, and Air Quality. [Sponsored by the Am. Meteorol. Soc., Oct. 19-22, 1976, Raleigh, N.C.] p. 46-49.

The model presented was designed to provide the time height distribution of temperature and wind during the course of the night given the geostrophic wind and the thermodynamic and mechanical properties of the surface.

35. Bonner, William D.
1968. Climatology of the low level jet. Mon. Weather Rev. 96(12):833-850.

Two years of wind data from 47 radiosonde stations in the United States are used to determine the graphical and diurnal variations in the frequency of strong low level wind maxima. Maximum frequency of occurrence is found in the Great Plains. Diurnal wind oscillations are examined. Oscillation is similar to that described by Blackadar.

36. Bonner, William D., S. Esbensen, and R. Greenberg.
1968. Kinematics of the low-level jet. J. Appl. Meteorol. 7(3):339-347.

Winds and vertical velocities are examined in ten southerly low-level jets. Some jets are strongly supergeostrophic. Air is typically rising downstream from the wind maximum and sinking just upstream from the jet core. This orientation of vertical velocities provides a possible explanation for the high frequency of nocturnal thunderstorms in the Midwest.

37. Bowen, A. J., and D. Lindley.
1974. Measurements of the mean wind flow over various escarpment shapes. Fifth Australasian Conf. on Hydraulics and Fluid Mechanics [Univ. Canterbury, Christchurch, New Zealand, Dec. 9-13, 1974]. p. 212-219.

Wind profiles were obtained to a height of 10 meters above the ground for various positions over a sloping and cliff escarpment. The local windspeed was compared with the undisturbed upstream wind at the same height and expressed as velocity ratios. Values at the velocity ratio varied widely but were commonly within the range of 1.1 to 1.4.

38. Bowen, A. J., and D. Lindley.
1977. A wind-tunnel investigation of the windspeed and turbulence characteristics close to the ground over various escarpment shapes. Boundary-Layer Meteorol. 12:259-271.

Four sharp-edged escarpments with slopes varying between a cliff and a 4:1 gradient were tested. The modifications to the mean wind, turbulence intensity, and energy spectra are described. Results suggest that significant changes in turbulence characteristics occur only in the wake region close behind the crest where a shift of energy to high frequency is evident.

39. Bradley, E. F.
1968. A micrometeorology study of velocity profiles and surface drag in the region modified by a change in surface roughness. Q. J. Royal Meteorol. Soc. 94(401):361-379.

Reports results of experiments where air passes from one surface to another with different roughness. The variation in surface stress and the development of velocity profiles were observed. A large portion of the surface stress adjustment occurs rapidly after transition. Growth of the modified region follows the 4/5 power law of boundary layer growth.

40. Brier, Glenn W.
1951. The statistical theory of diffusion by turbulent eddies. *In* An atmospheric pollution: a group of contributions. Meteorol. Monogr. 1(4):15-19.

Discusses some of the most important unsolved problems of statistical turbulent theory and the difficulties in applying the theory to diffusion in the atmosphere.

41. Brook, R. R., and K. T. Spillane.
1968. The effect of averaging time and sample duration on estimation and measurement of maximum wind gusts. J. Appl. Meteorol. 7(4):567-574.

The ratio of maximum gust drawn from a sample to the ratio of a second maximum gust drawn from a second sample is derived. A spectral density function is defined so that only one parameter has any effect on the ratio. Suggested practical uses include aviation landing advice for aircraft particularly sensitive to wind gusts.

42. Brook, R. R., and K. T. Spillane.
1970. On the variation of maximum wind gusts with height. J. Appl. Meteorol. 9(1):72-78.

For stationary strong-wind regimes dominated by "mechanical turbulence," maximum gusts are determined as a function of height and averaging time. The technique presented should permit those interested to interpret presently available extreme-wind gusts data in terms of height and averaging times appropriate to their problem.

43. Brooks, F. A.
1961. Need for measuring horizontal gradients in determining vertical eddy transfers of heat and moisture. J. Meteorol. 18(5):589-596.

Reviews problems and results dealing with irregular shear stress profiles produced by flow over a change in surface roughness. Tree interference effects may still be evident even at a distance of 50 tree heights.

44. Brown, Arthur A., and Kenneth P. Davis.
1973. Forest fire: control and use. 2d ed. 686 p. McGraw-Hill Book Co., New York.

The association of wind with fire is discussed in this book. Chapter 7 deals with the effect of wind on fire.

45. Brown, James M.
1972. The effect of overstory removal upon surface wind in a black spruce bog. USDA For. Serv. Res. Note NC-137, 2 p. North Cent. For. Exp. Stn., St. Paul, Minn.

Wind passage was measured over a black spruce canopy at the surface, both under the canopy and in a clearcut strip. Wind below the canopy was 10 percent of that above the canopy; wind in the clearcut strip was 45 percent of the wind above the canopy.

46. Buajitti, K., and A. K. Blackadar.
1957. Theoretical studies of diurnal wind-structure variations in the planetary boundary layer. Q. J. Royal Meteorol. Soc. 83(358):486-500.

The cause of wind variations was sought by finding what periodic variations occur when eddy viscosity is periodic in time and constant with height and when the eddy viscosity is distributed arbitrarily with height. It was concluded that the observed variations can occur only when both the average value of the eddy viscosity and the amplitude of its variations decrease rapidly with height in the lowest third of the friction layer.

47. Buettner, Konrad J. K., and Norman Thyer.
1965. Valley winds in the Mount Rainier area. Archiv. Meteorol., Geophysik and Bioklimatol. Serie B: Alligeméine und biologische klimatologie 14(2):125-147. [In English.]

Airflow within a mountain valley is up the valley during the day and down at night and is compensated by a return flow (antiwind) at a higher level. Speeds reach a maximum in early afternoon and just before sunrise. When a well developed wind system occurred in one valley, well developed systems tended to occur in other valleys in the same area.

48. Bull, G. A. D., and E. R. C. Reynolds.
1968. Wind turbulence generated by vegetation and its implications. *In* Wind effects in the forest. [Suppl. to Forestry, J. Soc. For., Great Britain.] p. 28-37. Oxford Univ. Press.

Wind measurements demonstrate the aerodynamically rough surface of a 26-year-old Scots pine plantation compared with 5-year-old Scots pine and short grass. A hydrostatic channel was used to demonstrate the relative efficiency of a leader of Scots pine to generate turbulence compared with Norway spruce and Douglas-fir leaders.

49. Burnham, J.
1970. Atmospheric gusts - a review of the results of some recent research at the Royal Aircraft Establishment. Mon. Weather Rev. 98(10):723-734.

Wind gusts at lower altitudes, including gusts in and near thunderstorms, were studied. The mathematical modeling of severe gusts relevant to aircraft design is described. Suggestions are made for models that may prove to be more accurate and more physically plausible.

50. Busch, Niels E., John A. Frizzola, and Irving A. Singer.
1968. The micrometeorology of the turbulent flow field in the atmospheric surface boundary layer. Acta Polytech. Scand., Physics including Nucleonics Series 59, 45 p. Copenhagen.

Outlines the background to the Monin-Obukhov similarity theory and extends the theory to the spectra of three-dimensional velocity flow. An analysis of data is presented and compared with other analyses.

51. Businger, J. A., J. C. Wyngaard, Y. Izumi, and E. F. Bradley.
1971. Flux-profile relationships in the atmospheric surface layer. J. Atmos. Sci. 28(2):181-189.

Wind and temperature profiles for a wide range of stability conditions have been analyzed in the context of Monin-Obukhov similarity theory. Direct measurements of heat and momentum fluxes enabled determination of the Obukhov length parameter. A comparison between profile-derived and measured fluxes showed good agreement over the entire stability range of the observations.

52. Byram, George M.
1954. Atmospheric conditions related to blowup fires. USDA For. Serv., Southeast. For. Exp. Stn., Pap. 35, 34 p. Asheville, N.C.

Extreme forest fire behavior is related to low-level jet winds. Various wind profiles that appear to be potential troublemakers are classified by four different types. Lists indicative conditions that give warning of unusual burning conditions.

53. Carl, Douglas M., Terry C. Tarbell, and Hans A. Panofsky.
1973. Profiles of wind and temperature from towers over homogeneous terrain. J. Atmos. Sci. 30(5):788-794.

With small Richardson numbers, no significant deviations from logarithmic profiles were detected up to 150 meters. Under nonneutral conditions, Monin-Obuskhov scaling described the profiles well.

54. Carruthers, Nellie.
1943. Variations in wind velocity near the ground. Q. J. Royal Meteorol. Soc. 69:289-301.

Summarizes the literature relevant to the subject of wind variation near the ground. The article deals with variation in mean wind with height and with gustiness and its relation to change of mean velocity and height. A general approximate law for variation of wind with height is suggested.

55. Cermak, J. E.
1970. Problems of atmospheric shear flows and their laboratory simulation. Boundary-Layer Meteorol. 1(1):40-60.

Presents a good review of air flow [illegible] extensive list of references.

56. Chiu, Arthur N. [illegible]
1974 [illegible]

[illegible] wind engineering research.

57. Chrosciewicz, Z.
1975. Correlation between wind speeds at two different heights within a large forest clearing in central Saskatchewan. Infor. Rep. NOR-X-141, 9 p. North. For. Res. Cent., Can. For. Serv., Edmonton, Alta.

Winds were measured at 1.2 meters and 10.0 meters above the ground. A straight-line relationship existed between windspeeds at two different heights. Tables were prepared for estimating midday winds at 10 meters from known winds at 4 meters height.

58. Cionco, Ronald M.

1965. A mathematical model for air flow in a vegetative canopy. J. Appl. Meteorol. 4(4):517-522.

A model was developed that expresses the surface roughness and the density and drag of a vegetative canopy. Computed canopy winds verified that the mixing length is nearly constant with height. Simulated wind profiles were in good agreement with observed data.

59. Cionco, Ronald M.

1972. A wind-profile index for canopy flow. Boundary-Layer Meteorol. 3(2):255-263.

The canopy wind profile is represented by an exponential function containing an index value of the airflow response to the vegetation. The index increases as both density and flexibility increase.

60. Cionco, Ronald M.

1979. A summary of an analysis of canopy index values for different canopy densities. *In* Fourteenth Conf. on Agric. and For. Meteorol. and Fourth Conf. on Bio-Meteorol. sponsored by the Am. Meteorol. Soc. [Minneapolis, Minn., April 2-6, 1979]. p. 107-109.

Windspeed profile data of two different canopy densities have been analyzed and the results indicate their indices of canopy flow behave in a similar manner. The good agreement lends credibility to the future usefulness of the canopy flow index.

61. Cliff, William C.

1977. The effect of generalized wind characteristics on annual power estimates from wind turbine generators. Battelle Memorial Inst., Pac. Northwest Lab., Richland, Wash., PNL-2436, 31 p.

Hourly windspeeds are assumed to have a Rayleigh frequency distribution which requires only a single parameter input (that is, mean value, variance, or higher moment values). A generic set of curves is developed to estimate the average power output of wind turbines.

62. Cliff, W. C., and G. H. Fichtl.

1978. Wind velocity-change (gust rise) criteria for wind turbine design. Battle Memorial Inst., Pac. Northwest Lab., Richland, Wash., PNL-2526, 17 p.

Formulas are developed for estimating the velocity change encountered over the swept area of a wind-turbine rotor system.

63. Cliff, W. C., C. G. Justus, and C. E. Elderkin.

1978. Simulation of the hourly wind speeds for randomly dispersed sites. Battelle Memorial Inst., Pac. Northwest Lab., Richland, Wash., PNL-2523, 21 p.

A technique is presented that simulates hourly windspeeds at any number of dispersed sites within a region. The required input is an hourly windspeed from a representative site and an estimation of size of the region in which the sites will be located.

64. Clodman, J.

1972. Small-scale motions. *In* Meteorological challenges: a history. p. 209-234. D. P. McIntyre, ed. Ottawa, Information, Canada.

Presents a discussion of the importance of mesoscale meteorological process. It is suggested that mesoscale meteorology is an important field of study that has been relatively neglected.

65. Cohen, Edward.

1960. Wind load on towers. *In* Topics of engineering meteorology. Meteorol. Monogr. 4(22):25-42.

A general theory of wind pressure for aerostatic effects and empirical-shape factors for common structural members is presented. Also reports test data on aerodynamic-lift (lateral force) coefficients.

66. Cooper, Robert W.

1965. Wind movement in pine stands. Ga. For. Res. Pap. 33, 3 p. Ga. For. Res. Counc., Macon.

A method is given for converting standard open winds (20 feet above ground) to those expected within different pine forest stands. A wind conversion table is provided for stands ranging from 20 to 70 feet high with basal areas of 20 to 100 square feet per acre.

67. Corby, G. A.

1954. The airflow over mountains. A review of the state of current knowledge. Q. J. Royal Meteorol. Soc. 80(346):491-521.

The review is confined mainly to the work of Quency and Scorer. Some experimental work with models in wind tunnels is considered briefly. A comprehensive field study by researchers who used gliders is summarized.

68. Cormier, Rene' V.

1975. Horizontal variability of vertically integrated boundary layer winds. J. Geophys. Res. 80(24):3407-3409.

The study shows that daytime root mean square windspeed differences are relatively independent of distance. At night, windspeed variability increases with increasing distance.

69. Corotis, Ross B.

1976. Stochastic modeling of site wind characteristics. Energy Res. and Dev. Admin., Div. Solar Energy Final Rep. ERDA/NSF/00357-76/1, 297 p.

Statistical methods and probability models are utilized to determine optimal evaluation procedures for survey data. Persistence of wind is measured in terms of velocity run duration. A general model is developed for the probability of run duration. The observed histograms for velocities exhibit a reasonable fit to both the Chi-square and Weibull distributions.

70. Corotis, Ross B.

1977. Stochastic modeling of site wind characteristics. U.S. Dep. Energy, Div. Solar Energy, Final Rep. RLO/2342-7/2, 143 p.

Statistical analysis procedures and probability models applicable to wind energy conversion sites are developed. Algorithms are used to study variances, fit probability distributions, analyze run duration, and determine correlation structure in the wind. Preliminary results indicate that the probability distributions for both wind velocity and power can be well modeled and calibrated from seasonal mean velocity alone.

71. Corotis, Ross B., Arden B. Sigl, and Michael P. Cohen.

1977. Variance analysis of wind characteristics for energy conversion. J. Appl. Meteorol. 16(11):1149-1157.

Autocorrelation and cross-correlation analyses confirm the existence of significant correlation in the wind at a single site for a period of 8 to 12 hours and between sites for similar time lags and separations up to 100 km or more.

72. Coulter, J. D.
1967. Mountain climate. *In* Proc. New Zealand Ecol. Soc. 14:40-57.

Climatic data are reported including free air and surface winds.

73. Countryman, Clive M., and DeVer Colson.
1958. Local wind patterns in Wildcat Canyon. USDA For. Serv. Tech. Pap. 28, 12 p. Calif. For. and Range Exp. Stn., Berkeley.

Observations are reported from a network of wind recording instruments. Local conditions frequently exert a major control on local wind patterns. Apparently only strong upper air patterns can extend influence to ground level in the small canyon studied.

74. Countryman, Clive M., M. A. Fosberg, and R. C. Rothermel.
1968. Fire weather and fire behavior in the 1966 Loop Fire. Fire Tech. 4(2):126-141.

The effect of Santa Ana winds on a major fire is described.

75. Cowan, I. R.
1968. Mass, heat, and momentum exchange between stands of plants and their atmospheric environment. Q. J. Royal Meteorol. Soc. 94(402): 523-544.

A model of mass and momentum transfer in the air layer occupied by a stand of plants is presented. An expression for windspeed is given in terms of the drag of the vegetation. Computed windspeed profiles are shown.

76. Cramer, H. E.
1960. Use of power spectra and scales of turbulence in estimating wind loads. *In* Topics in engineering meteorology. Meteorol. Monogr. 4(22):12-18.

Measurements of turbulent wind structure are summarized and application of data to the problem of estimating wind forces is discussed. Estimates of maximum wind gusts may be based on the mean windspeed assuming an average turbulent intensity and the windspeed fluctuations are approximately gaussian.

77. Cramer, Owen P., and Robert E. Lynott.
1961. Cross-section analysis in the study of windflow over mountainous terrain. Bull. Am. Meteorol. Soc. 42(10):693-702.

The cross-section charts help in tracing airflow over local obstacles and portray changes in stability. Evidence is given that potential temperature patterns must be considered in the analysis of wind structure in mountain areas.

78. Crosby, John S., and Craig C. Chandler.
1966. Get the most from your windspeed observation. Fire Contr. Notes 27(4):12-13. USDA For. Serv., Washington, D.C.

The probable fastest 1-minute windspeed, the average, and highest momentary gust is given based on observations made at Salem, Mo., during several fire seasons. A table is given to convert from gust windspeed at 5 feet above the ground to the standard 20-foot, 10-minute speed for stable, neutral, and unstable conditions.

79. Cylke, Thomas R.
1978. The destruction of surface based inversions by wind shear turbulence over northern Nevada. Conference on Sierra, Nevada meteorolgy [sponsored by Am. Meteorol. Soc. and USDA For. Serv., South Lake Tahoe, Calif., June 19-21, 1978]. p. 97-100.

The relationship between the Richardson number and the time a temperature inversion breaks up was established. An equation is given expressing the time after sunrise of surface winds greater than 7 knots in terms of the Richardson number.

80. Danard, Maurice.
1977. A simple model for mesoscale effects of topography on surface winds. Mon. Weather Rev. 105:572-581.

A diagnostic, one-level, primitive equation model for computing influences of orography, friction, and heating on surface winds is described. The model works best for orographic channeling. It was applied to Juan de Fuca and Georgia Straits in British Columbia using a grid size of 10 kilometers.

81. Daniels, P. Anders, Bruce E. Palmer, Thomas G. Tarlton, and Thomas A. Schroeder.
1976. A survey of the winds on the Island of Maui for potential wind power generation. part 1: mobile sampling program August 7-26, 1976. 67 p. Dep. Meteorol., Univ. Hawaii.

Maps of surface isotachs and streamlines revealed pronounced diurnal cycles. Diurnal variation in vertical structure also appeared. Physical hypotheses are offered to explain the diurnal patterns.

82. Davenport, A. G.
1961. The spectrum of horizontal gustiness near the ground in high winds. Q. J. Royal Meteorol. Soc. 87(372):194-211.

Describes the spectra of the horizontal components of gustiness in strong winds. Cross-spectra and cross-correlations of velocity between pairs of stations on a mast are given. It appears that cross-spectra can be expressed as a simple function of the ratio of the vertical separation to wavelength.

83. Davidson, Ben.
1963. Some turbulence and wind variability observations in the lee of mountain ridges. J. Appl. Meteorol.

are associated with the transition zone between the wind shadow just above the slope and the prevailing flow. The transition zone is usually characterized by sustained verti-

The increase of gust windspeeds with height is markedly less than that of mean windspeeds. At times of maximums the gust windspeed is approximately proportional to the height raised to the power of 0.085. The corresponding index for mean windspeed is 0.16.

86. Deacon, E. L.
1973. Geostrophic drag coefficients. Boundary-Layer Meteorol. 5(3):321-340.

Data on the relationship of the surface wind to the geostrophic wind at Parton Down, Salisbury Plain, are presented for various stability conditions and analyzed in light of the Rossby-number similarity theory.

87. Defant, Friedrich.
1951. Local winds. *In* Compendium of meteorology. p. 655-672. T.F. Malone, ed. Am. Meteorol. Soc., Boston, Mass.

Local winds are considered to be those winds where the friction terms are of the same order of magnitude as the pressure gradient terms and the Coriolis and acceleration terms may be neglected. The range is of the order of 10 km or less. These include land and sea breezes, mountain and valley winds, and jet effect winds. The basic principles of these local winds are discussed.

88. DeMarrais, Gerard A.
1959. Wind-speed profiles at Brookhaven National Laboratory. J. Meteorol. 16(2):181-190.

A comparison of results obtained through the use of the power law and the logarithmic law shows the former more accurately fits the data. The results are also compared with those obtained at 10 other locations.

89. DeMarrais, Gerard A., George L. Dowing, and Herbert E. Meyer.
1968. Transport and diffusion of an aerosolized insecticide in mountainous terrain. ESSA Res. Lab. Tech. Memo ARL 6, 46 p. Silver Springs, Md.

Data are presented to serve as a hypothesis on the transport and diffusion mechanisms in and over a forest in mountainous terrain. The general air flow in V-shaped and U-shaped valleys is given. A composite physical model of the temperature structure and air flow was developed.

90. Den Hartog, Gerrit, and Roger H. Shaw.
1975. A field study of atmospheric exchange processes within a vegetative canopy. *In* Heat and mass transfer in the biosphere. Part 1. Transfer processes in plant environment. p. 299-309. D. A. deVries and N. H. Afgan, eds. Scripta Book Co., Washington, D.C.

Measurements within a mature canopy of corn included mean temperature and windspeed profiles, eddy fluxes, and leaf area density. Direct evaluation of leaf drag and eddy transport coefficients for heat and momentum were obtained. Leaf drag coefficient was nearly constant with height and windspeed. Eddy coefficients were within 30 percent of each other and decreased approximately exponentially with depth in the canopy in a manner similar to the mean wind profile.

91. Denmead, O. T.
1964. Evaporation sources and apparent diffusivities in a forest canopy. J. Appl. Meteorol. 3(4):383-389.

Measurements of momentum suggest that, even for light winds, transfer processes within the canopy are turbulent in nature and that the level of turbulence is probably associated with momentum transfer.

92. DeVito, Anita, and David R. Miller.
1977. The effects of corn and oak vegetation on cold air drainage. *In* Weather-climate modeling for real-time applications in agriculture and forest meteorology [preprints from 13th Agric. and For. Meteorol. Conf., Am. Meteorol. Soc., Purdue Univ., West Lafayette, Ind., April 4-6, 1977].

Wind profiles show maximums below and above the canopies. The incident of drainage is higher below the oak canopy when protected from ambient wind mixing. The data plots resemble those of Bergen. Values predicted by two air drainage models were not accurate for airflow beneath the corn and oak canopies.

93. Drake, Ronald L.
1977. Methods for siting small wind machines. Battelle Pac. Northwest Labs, BNWL-SA-6297, 21 p. Richland, Wash.

The flow of air over rough surfaces and hilly terrain and the technical issues concerning wind energy conversion systems are discussed.

94. Dubov, A. S., and L. P. Bykova.
1974. Turbulence in forest canopies. Atmos. and Ocean Physics 10(6):650-652.

A nonlinear equation system and the Kolmogorov relations are used to solve the two-layer problem of finding average wind velocity profiles and turbulence characteristics above and within a horizontal homogeneous forest.

95. Durst, C. S.
1960. Wind speeds over short periods of time. The Meteorol. Mag. 89(1056):181-186.

A statistical assessment is made of windspeeds in short intervals of time. The standard deviation of short-period means and the probable value of the maximum windspeed given the mean hourly speed are included.

96. Egan, Bruce A.
1975. Turbulent diffusion in complex terrain. *In* Lectures on air pollution and environmental impact analysis [sponsored by Am. Meteorol. Soc., Boston, Mass., Sept. 29-Oct. 3, 1975]. Chap. 4, p. 112-135. Duane A. Haugen, workshop coordinator.

The airflow phenomena in regions of complex terrain are discussed. Some examples of model studies of flow are given.

97. Elliott, William P.
1958. The growth of the atmospheric internal boundary layer. Trans. Am. Geophys. Union 39(6):1048-1054.

An internal boundary layer over a new surface grows as the four-fifths power of distance downwind and is independent of windspeed. The effect of thermal stability is small.

98. Ellsaesser, Hugh W.
1969. Wind variability as a function of time. Mon. Weather Rev. 97(6):424-428.

Published wind variability data are examined and found to be generally consistent with predictions based on Kolmogorov's similarity hypothesis of locally homogeneous isotropic turbulence.

99. Fichtl, George H., John W. Kaufman, and William W. Vaughan.
1969. Characteristics of atmospheric turbulence as related to wind loads on tall structures. J. Spacecraft and Rockets 6(12):1396-1403.

A boundary-layer wind model is presented based on Kennedy Space Center data. Peak wind profiles are specified. Empirical formulas are used to estimate gust factors. A special model of turbulence for neutral boundary layer (high windspeeds) accounts for the vertical variation of turbulence power spectra.

100. Finklin, Arnold I.
1973. Meteorological factors in the Sundance Fire Run. USDA For. Serv. Gen. Tech. Rep. INT-6, 46 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Strong sustained winds were a major factor in the Sundance Fire Run in northern Idaho on Sept. 1, 1967. The winds were caused by a strong pressure gradient ahead of an approaching trough. Surface winds were around 35 mi/h at exposed ridgetop locations with gusts of 50-55 mi/h in the fire area. Various aspects of the weather situation are examined.

101. Fleagle, Robert G.
1950. A theory of air drainage. J. Meteorol. 7(3):227-232.

Drainage velocity is found to vary periodically about an equilibrium value that is proportional to the net outgoing radiation, and inversely proportional to the cooling height and the slope of the ground. An assumed friction force that is proportional to the square of the velocity gives fairly realistic results.

102. Flemming, G.
1968. Die windgeschumdigkeit auf waldungebenen freiflachen. [The velocity of wind in clearings surrounded by forests.] Archiv Fuorstwes. 17(1):5-16. [Transl. Dep. Fish. For. Can. OOFF-60, 1969, 20 p.]

The mean wind velocity in clearings compared to that in open fields is calculated. Calculations are performed for square and oblong clearings of various sizes and orientation. Many figures showing relative windspeeds are given.

103. Fons, Wallace L.
1940. Influence of forest cover on wind velocity. J. For. 38(6):481-486.

Observations of wind velocity in pine, brush, and grass cover type are offered. Figures and equations descriptive of wind movement in forested country are presented.

104. Fosberg, Michael A.
1967. Numerical analysis of convective motions over a mountain ridge. J. Appl. Meteorol. 6(5):889-904.

The convection associated with a valley wind regime was analyzed by numerical techniques. Numerical simulations reproduced most of the features and processes of the valley wind system. The afternoon quasi-steady state motion of the valley wind results from an apparent maximum rate of conversion of potential to kinetic energy.

105. Fosberg, Michael A.
1969. Airflow over a heated coastal mountain. J. Appl. Meteorol. 8(3):436-442.

Observations of airflow over the Santa Ana Mountains were analyzed by numerical techniques. Flow can be divided into three distinct stages. The first stage is that of valley wind required with ridgetop convection. The second and third stages are associated with flow across the ridge. A wavelike motion is produced in response to the thermal field.

106. Fosberg, Michael A., William E. Marlatt, and Lawrence Krupnak.
1976. Estimating air flow patterns over a complex terrain. USDA For. Serv. Res. Pap. RM-162, 16 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

A 1-layer model of airflow was developed for use in complex terrain. The resultant solutions describe a diagnostic model of the vector flow field. The model can be used in areas with less dense observational networks.

107. Frasier, Alistair B., Richard C. Easter, and Peter V. Hobbs.
1973. A theoretical study of the flow of air and fallout of solid precipitation over a mountain terrain. Part 1. Airflow model. J. Atmos. Sci. 30(5):801-812.

The equation for steady, two-dimensional, laminar inviscid flow over a broad ridge, including latent heat release, is derived. The model indicates the dynamical effects of latent heat are significant in some cases but are generally secondary to the barrier effect of the terrain.

108. Frederick, Ralph H.
1961. A study of the effect of tree leaves on wind movement. Mon. Weather Rev. 89(1):39-44.

Windflow at tree-influenced stations was studied during foliation and defoliation in Nashville, Tenn. It was found to be 25 to 40 percent greater during periods of defoliation.

109. Frenkiel, J.
1962. Wind profiles over hills (in relation to wind-power utilization). Q. J. Royal Meteorol. Soc. 88:156-169.

The wind was investigated at two sites: (1) a hill forming part of a ridge, and (2) an isolated peak. At each site, measurements of vertical gradient, direction, and air temperature gradient up to 40 meters above hilltop for a period of 1 year were obtained and are given.

110. Frenkiel, J.
1963. Gusts over hills (in relation to wind-power utilization). Q. J. Royal Meteorol. Soc. 89(380): 281-283.

Wind gusts over two hills are described. [illegible] ence in the ratio of gust variation with height t[illegible] velocity for the tw[illegible] the wind [illegible]

111. Fre[illegible]

1970. Dispersion of air tracers into and within a forested area: 3. U.S. Army, Atmos. Sci. Lab. ECOM-68-G8-3, 53 p. Fort Huachuca, Ariz.

Vegetation density was found to have a strong influence on air flow within the forest. Winds within the forest were not strongly coupled to wind above the forest. Many figures showing windspeed profiles within the forest are given.

114. Fujita, Tetsuya, Kenneth A. Styber, and Roger A. Brown.

1962. On the meso-meteorological field studies near Flagstaff, Arizona. J. Appl. Meteorol. 1(1):26-42.

Statistics of the Elden Mountain wind are discussed. A nocturnal wind at low levels, which greatly resembles the low-level jet wind over the Midwest reported by Blackadar, was discovered. Detailed analysis of a summer storm is given.

115. Furman, R. William, and Glen E. Brink.

1975. The National Fire Weather Data Library: what it is and how to use it. USDA For. Serv. Gen. Tech. Rep. RM-19, 8 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

The library is a collection of daily weather observations from fire weather stations across the nation. Examples are given for using the library on the UNIVAC 1108 computer at the Fort Collins Computer Center.

116. Garratt, J. R.

1977. Review of the drag coefficients over oceans and continents. Mon. Weather Rev. 105:915-929.

Low relief topography and low mountain peaks require a geostrophic drag coefficient of 3×10^{-3}, while land surfaces in general require 2×10^{-3}, for which the drag at 10 meters is 10×10^{-3} and the effective roughness length is approximately 0.2 meters.

117. Gary, Howard L.

1974. Canopy weight distribution affects wind speed and temperature in a lodgepole pine forest. For. Sci. 20(4):369-371.

Windspeeds were minimum and midday temperatures maximum in the midcanopy region where needles and branch weight were concentrated.

118. Geiger, Rudolf.

1966. Das Klima der bodennachen Luftschicht. [The climate near the ground.] Harvard Univ. Press, Cambridge, Mass. [Transl. by Scripta Technica, Inc., 4th. German ed.]

A classic. Examples and discussion of the wind field (and other variables) are given including that in forests and mountains.

119. Gerhardt, J. R.

1962. An example of a nocturnal low-level jet. J. Atmos. Sci. 19(1):116-118.

Observations were obtained from a 1,400-foot tower, near Dallas, Tex. The time-height variations of the low-level jet wind are given.

120. Gifford, Frank Jr.

1953. A study of low level air trajectories at Oak Ridge, Tennessee. Mon. Weather Rev. 81(7):179-192.

The properties of low-level airflow, particularly of vertical velocity patterns, are displayed in various ways. Thermal-dynamical slope winds apear to contribute more to these patterns than a purely mechanical effect.

121. Gilman, C. S., and L. L. Weiss.

1950. A numerical solution for irrotational flow over a mountain barrier. Trans. Am. Geophys. Union 31(5):699-706.

The "relaxation method" is applied to Pockel's equation for a case of flow over a given mountain profile. Results are compared to those of others. Different methods give different results, the principal difference being in vertical velocities at higher elevations.

122. Gisborne, H. T.

1941. How the wind blows in the forest of northern Idaho. USDA For. Serv. Prog. Rep., North. Rocky Mt. For. and Range Exp. Stn., 12 p. Missoula, Mont.

Includes a unique set of charts that give the maximum, minimum, and average wind velocities at various heights in an old-age, dense conifer forest stand.

123. Glahn, Harry R.

1970. A method for predicting surface winds. Environ. Sci. Serv. Admin. Tech. Memo. WBTM TDL 29, 18 p. Silver Springs, Md.

Various regression models are discussed and applied to available data. Verification demonstrated usefulness of the objective technique.

124. Gleeson, Thomas A.

1951. On the theory of cross-valley winds arising from differential heating of the slopes. J. Meteorol. 8:398-405.

Expressions are derived for a cross-valley wind. Friction, inertia, the Coriolis force, time of day and year, latitude, orientation of the valley, and inclinations of the slopes are independent variables. Several examples illustrating effects of the independent variables on the wind are discussed.

125. Gleeson, Thomas A.

1953. Effects of various factors on valley winds. J. Meteorol. 10(4):262-269.

A relation is derived for the periodic valley wind as a function of time and elevation, in terms of the diurnal temperature variation, slope of the valley floor, eddy viscosity, the Coriolis force, and a pressure force representing the constraining effect of the valley walls.

126. Gloyne, R. W.

1968. The structure of the wind and its relevance to forestry. *In* Wind effects on the forest. p. 7-19. Supp. to Forestry, J. Soc. For. G.B., Oxford Univ. Press.

This paper provides brief comments on: (1) features of large-scale wind systems; (2) surface wind, in particular, gales and extreme winds in the British Isles; (3) effects of landscape features on wind near the surface; and (4) effects of surface friction on low-level airflow.

127. Goff, R. C., J. T. Lee, and E. A. Brandes.

1977. Gust front analytical study. U.S. Dep. Transp. Rep. FAA-RD-77-119, 126 p. Washington, D.C.

Observations of a gust front evolution associated with severe thunderstorm are shown. Turbulence and multiple surges are discussed.

128. Golding, E. W., and R. I. Harris.

1976. The generation of electricity by wind power. 332 p. John Wiley & Sons, Inc., New York.

Earlier studies of windflow over hills are given in chapter 7. Many references are included.

129. Goodwin, William R., Gregory J. McRae, and John H. Seinfeld.

1979. A comparison of interpolation methods for sparse data: application to wind and concentration fields. J. Appl. Meteorol. 18:761-771.

Various techniques were compared using three data sets: (1) a concentration distribution to which the exact solution was known; (2) a potential flow field; and (3) surface ozone measured in the Los Angeles basin. Results indicate that fitting a second-degree polynomial, with each data point weighted according to distance, provides a good compromise between accuracy and computational cost.

130. Grace, J.

1977. Plant response to wind. 204 p. Academic Press: London, New York, San Francisco.

Brings together material scattered among several disciplines. Discusses shelter effects in terms of physiology of plants and the microclimatology of crops. Practical problems of wind damage in agriculture and forestry are discussed.

131. Greene, G. E., H. W. Frank, A. J. Bedard, Jr., and others.

1977. Wind shear characterization. U.S. Dep. Transp. Rep. FAA-RD-77-33, 120 p. Washington, D.C.

Thunderstorm gust front is a major source of low-level wind shear. Several gust front events are analyzed in detail and compared with theoretical models and laboratory studies. Results draw a relationship between gust-front speed of motion and maximum shear.

132. Greenway, M. E.

1978. An analytical approach to wind velocity gust factors. Univ. Oxford Eng. Lab., O.U.E.L. Rep. 1241/78, 44 p.

An equation was derived for determining wind velocity gust factors. The gust factors were found to be linearly dependent on turbulent intensity. Good agreement was found between the predictions of the analysis and measurements made in a wind tunnel.

133. Gurka, James J.

1976. Satellite and surface observations of strong wind zones accompanying thunderstorms. Mon. Weather Rev. 104(12):1484-1493.

The strength of thunderstorm gust fronts can frequently be determined from satellite-derived speed of clouds associated with gust fronts and the appearance of cloud patterns. Rapidly moving gust fronts are associated with strong surface winds. The region of most vigorous convection can be pinpointed by the cloud-edge gradients and appearance of anvil cirrus on enhanced infrared imagery.

134. Hanna, Steven R.

1979. Some statistics on Lagrangian and Eulerian wind statistics. J. Appl. Meteorol. 18(4):518-525.

Reports study of methods of estimating Lagrangian or Eulerian wind fluctuations at one time based on knowledge of wind fluctuations at some previous time. Various concepts were tested using data from Minnesota, Nevada, and Idaho.

135. Hardy, Donald M.

1978. Principle components analysis of vector wind measurements. J. Appl. Meteorol. 17(8):1153-1162.

The method of principal components analysis was generalized to the treatment of vector fields of data and applied to a 12-month record of mean hourly wind velocities from 10 locations in a mesoscale region. Applications of the generalized vector formulation are discussed.

136. Harris, Eugene K., and Robert A. McCormick.

1963. A simple procedure for estimating the standard deviation of wind fluctuations. J. Appl. Meteorol. 2(6):804-805.

A method is derived and tested to estimate the standard deviation of wind fluctuations using amplitude of wind vane fluctuations and the number of wind direction reversals.

137. Hawkes, H. Bowman, and Raymond Wexler.

[n.d.] Local winds: mountain and valley winds, land and sea breezes. 45 p. U.S. Army, Eatontown Signal Lab. Group, Dugway Proving Ground, Tooele, Utah.

A compilation of acceptable theories and facts that pertain to local winds was prepared for forecasters.

138. Hennessey, Joseph P., Jr.

1977. Some aspects of wind power statistics. J. Appl. Meteorol. 16(2):119-128.

The Weibull probability density function is upheld and discussed as a good model for windspeed distributions. The Weibull model is applied to three Oregon windpower sites. It is concluded that the Weibull model has many computational advantages.

139. Hewson, E. Wendell, John E. Wade, and Robert W. Baker.

1977. Vegetation as an indicator of high wind velocity, phase 1. U.S. Dep. Energy, Div. Solar Energy, Final Rep. RLO/2227-T24-77/2, 58 p.

Five different indices of wind effects on trees have been developed and are presently being calibrated in terms of various wind characteristics. Among factors affecting the response of these indicators are exposure, slope, and tree species. Field studies are presently being conducted in the Columbia Gorge and in western Oregon.

140. Hicks, B. B., P. Hyson, and C. J. Moore.

1975. A study of eddy fluxes over a forest. J. Appl. Meteorol. 14(1):58-66.

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142. Holruyd, Edmond W., III.

1970. Prevailing winds on White Fish Mountain as indicated by flag trees. For. Sci. 16(2):222-229.

The direction of branch growth and the position of reaction wood in the trunk tops were studied to determine the direction of prevailing winds. A very complex wind pattern was found.

143. Hsi, G., and J. H. Nath.

1970. Wind drag within simulated forest canopies. J. Appl. Meteorol. 9(4):592-602.

The local drag coefficients, aerodynamic roughness, and wind velocity profiles were studied for a simulated forest and bushy canopy using a wind tunnel. It was found feasible to establish the relationship between model and prototype canopies for flow characteristics.

144. Huang, C. H., and D. L. Drake.

1979. A direct method of adjusting windfield over complex terrain. *In* Fourteenth Conf. on Agric. and For. Meteorol. and Fourth Conf. on Bio-Meteorol. [sponsored by the Am. Meteorol. Soc., Minneapolis, Minn., April 2-6, 1979]. p. 102-104.

A generalized direct method for adjusting wind fields was developed. The mass-consistent model computes wind fields over complex terrain in a terrain conformal coordinate system. The method is expected to reduce formulation.

145. Huss, P. O.

1974. Estimation of distributions and maximum values of horizontal wind speeds. J. Appl. Meteorol. 13(6):647-653.

Statistical analysis suggests that distributions of the ratios of time units (monthly, daily, etc.) to the long-range average windspeeds are similar for different locations. Also, it was found that the distributions of the ratios of the maximum to the average windspeed, or its square root, could be used to estimate expected maxima. Several distributions are shown.

146. Hutte, Paul.

1968. Experiments on windflow and wind damage in Germany; site and susceptibility of spruce forests to storm damage. *In* Wind effects on the forest. p. 20-26. Supp. to Forestry, J. Soc. For. G.B. Oxford Univ. Press.

This paper deals with the influence of topography, including mountain ridges and valleys, and soil on windthrow.

147. Inoue, E.

1963. On the turbulent structure of airflow within crop canopies. J. Meteorol. Soc. Japan 41(6): 317-325.

Canopy-eddy size has been suggested to be constant with height within the canopy layer. Velocities decreased downward following an exponential expression. Vertical transfer coefficients of airflow are discussed and tested with eariler observations.

148. Irwin. John S.

1979. A theoretical variation of the wind profile power-law exponent as a function of surface roughness and stability. Atmos. Environ. 13:191-194.

The variation of the wind profile power-law exponent with respect to changes in surface roughness and atmospheric stability is depicted. Theoretical estimates of the power-law exponent compare favorably with power-law exponent data from various sources.

149. Izumi, Yutaka.

1964. The evolution of temperature and velocity profiles during breakdown of a nocturnal inversion and a low-level jet. J. Appl. Meteorol. 3(1):70-82.

Turbulent mixing appears to play a major role in the breakdown of the observed inversion and in dissipation of the low-level jet wind.

150. Izumi, Yutaka, and Morton L. Barad.

1963. Wind and temperature variations during development of a low-level jet. J. Appl. Meteorol. 2(5):668-673.

Systematic variations of windspeed and air temperature are discussed to illustrate the orderly development of a low-level jet wind and the vertical extent of the mixing process within a deepening inversion.

151. Jackson, Julius Augustus, Jr.

1978. Diurnal variation of wind profiles across mountainous terrain during an air stagnation period. M.S. thesis. N.C. State Univ., Raleigh. 63 p.

Oscillation in lower levels showed the presence of a low-level jet wind. In an easterly flow, the jet reaches a maximum at about 0600 G.M.T. at 300 meters above ground level. The jet is due to an air inertial type oscillation driven by the diurnal variation of friction forces aided by thermal forcing.

152. Jackson, P. S.

1975. A theory for flow over escarpments. *In* Proc., Fourth Int. Conf. on Wind Effects on Buildings and Structures [Heathrow, 1975]. p. 33-39. Keith J. Eaton, ed. Cambridge Univ. Press: London, New York, Melbourne.

An analytical theory for the flow of a fully developed turbulent boundary layer over low two-dimensional humps is described. A particular case of air escarpment is examined in detail.

153. Jackson, P. S., and J. C. R. Hunt.

1975. Turbulent wind flow over a low hill. Q. J. Royal Meteorol. Soc. 101: 929-955.

An analytical solution is presented for the flow of an adiabatic turbulent boundary layer on uniformly rough surface over a two-dimensional hump with small curvature. It is found that, at the point above the top of a low hill at which the increase in velocity is a maximum, the velocity is about equal to the velocity at the same elevation above level ground upwind of the hill. The theory may be useful in giving rough estimates of the effect of hills on wind.

154. Jarvis, P. G., G. B. James, and J. J. Landsberg.

1976. Coniferous forests. *In* Vegetation and the atmosphere, vol. 2, case studies. p. 171-240. J. L. Monteith, ed. Academic Press, New York, London.

This review includes studies and measurements of momentum exchange within forest canopies. Measurements and data are given.

155. Jensen, Niels Otto.

1978. Change of surface roughness and the planetary boundary layer. Q. J. Royal Meteorol. Soc. 104(440):351-356.

The ratio between upstream and far downstream surface friction velocities relative to change in surface friction is given on basis of results from the surface Rossby number similarity theory. It is found that even at distances such that the internal boundary layer has grown to the full height of the planetary boundary layer the surface stress still considerably exceeds the equilibrium value.

156. Jensen, Niels Otto, and Ernest W. Peterson.
1978. On the escarpment wind profile. Q. J. Royal Meteorol Soc. 104:719-728.

Various theories for flow over low ridges give results consistent with each other, and these results can be used to quantify certain observed features of the wind profile downwind from an escarpment.

157. Johnson, Glenn T.
1979. Evaluation of schemes for estimating surface wind strength. Atmos. Environ. 13(4):437-442.

Three methods of estimating local surface-wind strength were compared. The methods include: assuming a uniform wind in a region, scaler interpolation between values measured by nearest instruments, and vector interpolation. The concept of the "windiness ratio," the local wind strength as a fraction of that at a reference station, improved the estimates of each method.

158. Johnson, O.
1959. An examination of the vertical wind profile in the lowest layers of the atmosphere. J. Meteorol. 16(2):144-148.

Windspeed increased more rapidly than predicted by the logarithmic law over prairie grass and a snow surface. The data were well represented by a simple power law except under strong inversion conditions. Over short grass, data were represented equally well by the two laws under diabatic and lapse conditions; the power law was better under inversion conditions.

159. Justus, C. G., W. R. Hargraves, Amir Mikhail, and Denise Graber.
1978. Methods of estimating windspeed frequency distributions. J. Appl. Meteorol. 17(3):350-353.

The Weibull function is discussed for representation of windspeed frequency distribution. The Weibull distribution gives smaller root-mean-square errors than the square-root-normal distribution when compared to observed windspeed. Methodology is available for projecting the observed Weibull distribution parameters at anemometer height to another height.

160. Justus, C. G., and Amir Mikhail.
1976. Height variation of windspeed and wind distribution statistics. Geophys. Res. Letters 3(5):261-264.

The power-law profile for windspeed is shown to be consistent with observed height variation of Weibull windspeed probability distribution functions that have been found to fit observed windspeed distributions.

161. Kaimal, J. C., J. C. Wyngaard, Y. Izumi, and O. R. Cote'.
1971. Behavior of spectra and cospectra of turbulence in the atmospheric surface layer. *In* Conf. on Air Pollution Meteorol. of the Am. Meteorol. Soc. [in cooperation with Air Pollution Control Assoc., Raleigh, N. C., April 5-9, 1971]. p. 22-29.

In the inertia subrange, the spectra of u, v, w, and θ (velocity components) fall according to a -5/3 power law and the cospectra of uw and wθ according to a -7/3 law. Interpolation formulas are given for the neutral spectra of velocity components, stress, and heat flux.

162. Kawatani, T., and R. N. Meroney.
1970. Turbulence and windspeed characteristics within a model canopy flow field. Agric. Meteorol. 7:143-158.

The study was carried out using roughness elements consisting of wooden pegs 9 cm high. The flow above the canopy was roughly approximated by the logarithmic profile; an exponential velocity profile holds well for the mean velocity within the canopy. The turbulent velocity within the canopy can be represented in exponential form and is related to the mean velocity at the top of the roughness.

163. Kepner, R. A., L. M K. Boelter, and F. A. Brooks.
1942. Nocturnal wind-velocity, eddy-stability, and eddy-diffusivity above a citrus orchard. Trans. Am. Geophys. Union 23:239-249.

The velocity profile above an orchard was approximated by a power function. The night conditions were generally of great stability with the least stability just above tree top where the wind velocity gradient was at a maximum. The values for eddy-diffusivity gave log-log plots.

164. Kerrigan, T. C.
1978. A technique for analyzing the structure of atmospheric turbulence. Battelle Memorial Inst., Pac. Northwest Lab., PNL-2509, 15 p. Richland, Wash.

A technique is devised to assess the contribution of large-scale coherent gust structures to the statistical properties of atmospheric turbulence.

165. Kerrigan, T. C.
1978. A verification statistic for numerical wind models. Battelle Memorial Inst., Pac. Northwest Lab., PNL-2510, 16 p. Richland, Wash.

A generalized wind estimate is computed at certain points in a geographic region. A point-by-point comparison with a numerical model prediction of wind is described. The comparison results in numerical assessments of the probability that the model succeeded in predicting the actual wind field.

166. Kerrigan, T. C.
1978. Spectral estimates of a wind fluctuation statistic pertaining to wind energy generators. Battelle Memorial Inst., PNL-2511, 26 p. Richla

An estimate of the frequen

stochastic model is constructed and mathematical foundations stated.

167. Kinerson, R., Jr., and L. J. Fritschen.
1971. Modeling a coniferous forest canopy. Agric. Meteorol. 8:439-445.

A Douglas fir stand was modeled by normalizing total

168. Kinerson, Russell S., Jr., and Leo J. Fritschen.
1973. Modeling air flow through vegetation. Agric. Meteorol. 12:95-104.

The authors assumed that the distribution of vegetation density controlled airflow within the forest. This hypothesis was tested by simulating the forest's surface area density distribution with a direct electrical analog computer. Comparison of model-generated and actual flow patterns is presented.

169. Kristensen, L., and H. A. Panofsky.
1976. Climatology of wind direction fluctuations at Risø. J. Appl. Meteorol. 15(12):1279-1283.

Standard deviations of wind direction fluctuations at 76 meters at Risø for the first half year of 1975 have been analyzed as functions of windspeed and temperature lapse rate. For strong winds, the standard deviation variance approaches a constant (about 3.5°). For lower speeds, the variance generally increases with decreasing stability. Largest values are found with weakest winds.

170. Landsberg, J. J., and G. B. James.
1971. Wind profiles in plant canopies. Studies on an analytical model. J. Appl. Ecol. 8:729-741.

Wind profiles measured in a spruce forest and published profiles for maize and an orange orchard are analyzed in terms of an independently derived model. The model fits well only over part of the measured profiles where foliage is not uniformly distributed. Also, the model does not allow separation of the drag coefficient and eddy viscosity terms.

171. Landsberg, J. J., and A. S. Thom.
1971. Aerodynamic properties of a plant of complex structure. Q. J. Royal Meteorol. Soc. 97(414): 565-570.

Coefficients of momentum and vapor transfer of spruce shoots in a wind tunnel were measured and shown to be dependent upon shoot density. Results indicate that the magnitude of the implied shelter effect is the same for water vapor as for momentum.

172. Leahey, Douglas M.
1974. A study of air flow over irregular terrain. Atmos. Environ. 8(8):783-791.

Measurements indicate that air flowing over river banks of moderate slope may parallel the terrain and that turbulence is greater than overregular topography.

173. Lee, R. J.
1975. Objective determination of surface winds in data sparse areas. Environ. Can. Atmos. Environ. Serv., Tech. Memo. TEC 828, 18 p. Downsview, Ont.

A computer program is described that objectively determines surface winds. A combination of theoretical and empirical concepts is utilized, including a dubbing routine to refine the surface pressure field. Some interpretation of the wind field is necessary.

174. Lenschow, Donald H., and Warren B. Johnson, Jr.
1968. Concurrent airplane and balloon measurements of atmospheric boundary-layer structure over a forest. J. Appl. Meteorol. 7(1):79-89.

A strong dependence of horizontal and vertical velocity variances upon stability was found. A clear distinction between the eddy sizes responsible for momentum transport in near-neutral and unstable situations is shown.

175. Leonard, R. E., and C. A. Federer.
1973. Estimated and measured roughness parameters for a pine forest. J. Appl. Meteorol. 12(2):302-307.

The roughness parameter (Z_O) and zero-plane displacement (d) were estimated from canopy map data using Kung's logarithmic formula and Lettau's equation for obstacle size and shape. Assumed values gave Z_O = 138 cm and d = 10.6 meters. Kung's formula gave Z_O = 75 cm and d = 9.7 meters. Measured profiles gave Z_O = 100 cm after d was fixed at a median value of 9.6 meters.

176. Lettau, H. H., and D. A. Haugen.
1961. Wind. *In* Handbook of geophysics, Rev. ed., chap. 5, sec. 1, (5-1) to (5-16). The MacMillan Co., New York.

A good review of the details of wind structure and the probabilities of occurrence of various windspeeds, shears, and gusts. Many tabulated data are included.

177. Leuning, R., and P. M. Attiwell.
1978. Mass, heat, and momentum exchanges between a mature Eucalyptus forest and the atmosphere. Agric. Meteorol. 19(3):215-241.

Zero plane displacement (d), roughness length (Z_O), and friction coefficients were determined from wind profiles under neutral conditions. It was assumed that these parameters were independent of atmospheric stability, and that d may be identified with the height of the mean sink for momentum within the canopy. A common value of d was used in the calculations of the fluxes of momentum, sensible heat, and CO_2.

178. Liu, C. Y., and W. R. Goodin.
1976. An iterative algorithm for objective wind field analysis. Mon. Weather Rev. 104(6):784-792.

Three different methods of analysis are investigated and compared with respect to the degree of minimization of wind divergence and the accuracy of wind data at a measured station. The reduction of wind divergence and the convergence of the iterative scheme are examined.

179. Liu, Mei-Kao, Pravin Mundkur, and Mark A. Yocke.
1974. Assessment of the feasibility of modeling wind fields relevent to the spread of brush fires. Final rep. 21-325, 142 p. Prepared for Forest Fire Lab., Pac. Southwest For. and Range Exp. Stn., Riverside, Calif.

The report includes a general discussion of modeling the wind field, a review of literature including a brief discussion of several different models, and the development of a two-level mesoscale flow model consisting of a fine-grid model embedded in a coarse-grid model. It is concluded that modeling the wind for simulation of fire spread is a realistic goal.

180. Lo, A. K.
1977. Boundary layer flow over gentle curvilinear topography with a sudden change in surface roughness. Q. J. Royal Meteorol. Soc. 103:199-209.

The effect of topography together with a rapid development of an internal boundary layer produced vertical windspeeds that reached a maximum of about 25 percent of the horizontal component. The perturbations due to a smooth-to-rough transition together with an increase of elevation are stronger than those generated from rough-to-smooth transition with a decrease of elevation.

181. Long, Robert R.

1953. Some aspects of the flow of stratified fluids. I. A theoretical investigation. Tellus 5:42-57.

This study relates to the problem of internal oscillations of a fluid in a gravity field with vertical gradients of density of velocity. A criterion is developed giving a sufficient condition for the motion to be uniquely determined by the configuration of the topography over which the fluid moves. Conditions favorable for the formulation of the internal "hydraulic jump" are discussed.

182. Long, Robert R.

1955. Some aspects of stratified fluids. III. Continuous density gradients. Tellus 7(3):341-357.

The results indicate a complicated laminar wave motion for obstacles of maximum height below a certain value. If obstacles are small enough to permit laminar or moderately turbulent motion, the reported experiments verify all important features of theory with remarkable fidelity. Larger obstacles cause considerable turbulence and blocking effects that propagate upstream, causing alternate maxima (jets) and minima of horizontal velocity in the vertical.

183. Lowry, Philip H.

1951. Microclimate factors in smoke pollution from tall stacks. *In* On atmospheric pollution: a group of contributions. Meteorol. Monogr. 1(4):24-29.

Wind direction and windspeed are discussed in terms of the Brookhaven wind gust classification. The classification is applied to the Sutton theory for maximum ground concentration of pollution.

184. Luna, R. E., and H. W. Church.

1974. Estimation of long-term concentrations using a "universal" wind speed distribution. J. Appl. Meteorol. 13(8):910-916.

Windspeed distributions from many diverse sites possess a quasi-universal shape which, when approximated analytically, can be adjusted to yield a distribution of windspeeds that have some specified mean value. The distributions are shown to be satisfactorily described by a log-normal function.

185. Lynott, Robert E., and Owen P. Cramer.

1966. Detailed analysis of the 1962 Columbus Day windstorm in Oregon and Washington. Mon. Weather Rev. 94(2):105-117.

The blowdown of timber in Oregon and Washington amounted to more than 11 million board feet producing long-term problems of fire and insect epidemics. The analysis included isobaric patterns and frontal positions at 1-hour intervals. The pressure pattern is used to determine location and magnitude of maximum winds.

186. McBean, Gordon A.

1968. An investigation of turbulence within the forest. J. Appl. Meteorol. 7(3):410-416.

The intensity of turbulence in a forest is as high as that over open ground. The cospectra of vertical velocity and temperature indicate the shape of the cospectra in the forest may be different from that over open ground. It may be necessary to obtain spatial as well as time averages of the turbulence heat fluxes and the net radiation in order to obtain a good energy balance.

187. McVehil, G. E.

1964. Wind and temperature profiles near the ground in stable stratification. Q. J. Royal Meteorol. Soc. 90:136-146.

Wind and temperature profiles are generally similar when the Richardson number is small. The log-linear wind profile fits observations well for Richardson numbers less than about 0.14. From the log-linear theory, heat flux and surface stress can be calculated given winds at two levels and the surface roughness.

188. Maitani, Toshihiko.

1977. Some turbulence characteristics in the surface layer over a wheat field. Berichte des Ohara Institute fur Landwirtshaftliche Biologie, Okayama Univeristat 17(1):29-46.

Results of a field study of turbulence over a wheat field are reported. The results are generally consistent with results obtained by other investigators.

189. Maitani, T.

1977. Vertical transport of turbulent kinetic energy in the surface layer over a paddy field. Boundary-Layer Meteorol. 12:405-423.

Turbulent kinetic energy and its vertical flux were measured at two heights over a paddy field. Frequent downward transport was found. Contributions to the downward transport arise mainly from the horizontal wind velocity component. Appreciable transport takes place intermittently in a few large downward bursts.

190. Maitani, T.

1978. On the downward transport of turbulent kinetic energy in the surface layer over plant canopies. Boundary-Layer Meteorol. 14:571-584.

The mechanism for downward transport of turbulent kinetic energy is investigated. Downward fluxes are predominent just above plant canopies and decrease with increasing height. An explanation is given in order to interpret the turbulent flow structure near plant canopies.

191. Maitani, T.

1978. Vertical transport of turbulent kinetic energy within pine woods. Berichte des Ohara Institute fur Landwirtschaftliche Biologie Okayama Universitat 17(3):159-16

Wind velocity fluctuation

pine forest

kine

Local strong wind appears under the lee of a mountain when air crosses over the mountain and is cooled by the earth's surface. Convection cells are produced in an unstable layer originating with heating from the ground in daytime. The character of such cells as gravity waves is discussed.

194. Mancuso, Robert Latimer.
1964. On the numerical integration of the steady state equation for air flow over a ridge. M.S. thesis. Univ. Wash., Seattle. 37 p.

The steady state air motion over a mountain ridge was described by solutions to a two-dimensional nonlinear equation of streamline displacement. Computational procedures proved to be stable and converge to unique solutions only when the coefficients satisfied certain restrictive conditions that were generally inconsistent with the assumption of stationary flow.

195. Manins, P. C., and B. L. Sawford.
1979. A model of katabatic winds. J. Atmos. Sci. 36:619-630.

Steady solutions show that katabatic winds are essentially supercritical on all practical slopes and the interfacial stress (between ambient and cooled air layers) due to mixing is the dominant retarding stress.

196. Markee, Earl H., Jr.
1963. On the relationships of range to standard deviation of wind fluctuations. Mon. Weather Rev. 91(1):83-87.

The findings indicate: (1) the wind-direction range shows promise for use as an indicator of the standard deviation of wind direction fluctuations near the ground; and (2) the windspeed range relationships to standard deviation of windspeed are not consistent.

197. Marston, Richard B.
1956. Air movement under an aspen forest and on an adjacent opening. J. For. 54(7):468-469.

Measurements were obtained at about 2 feet above ground in a thick stand of aspen and in rectangular opening about 70 by 200 feet in size. The airflow in the opening averaged 4.57 times that in the stand. On one day, it was 74 times greater. In spring, before the leaves were fully developed, the air movement averaged only 1.4 to 2.0 times greater in the opening. The relative reduction in windspeed under the aspen was 78 percent for the entire measurement period.

198. Martin, H. C.
1971. Average winds above and within a forest. J. Appl. Meteorol. 10(6):1132-1137.

When the atmosphere is stable, variations in wind profile shape above the forest are associated largely with site properties. During the day, variations are less, indicating that convection turbulence tends to control the profile shapes and to mask the effect of site irregularities. The ratio of windspeed in the trunk space to windspeed above the canopy reaches a maximum at noon and drops to 75 percent of its maximum value at night.

199. Marunich, S. V.
1975. Some characteristics of turbulent exchange between a forest and the atmosphere. Soviet Hydrology: Selected Papers. Issue No. 2, p. 51-54.

Analysis of turbulent exchange was based on measurements made in pine and birch forests. Among other findings, the results reveal the existence of a buffer layer above the forest, only above which the main relations of the similarity theory are satisfied.

200. Mason, P. J., and R. I. Sykes.
1978. On the interaction of topography and Ekman boundary layer pumping in a stratified atmosphere. Q. J. Royal Meteorol. Soc. 104(440):475-490.

Numerical results for flow over a two-dimensional ridge confirm theoretical prediction that stratification enhances momentum coupling and produces a low-level jet parallel to the ridge.

201. Mason, P. J., and R. I. Sykes.
1979. Flow over an isolated hill of moderate slope. Q. J. Royal Meteorol. Soc. 105:383-395.

A two-dimensional theory of Jackson and Hunt for turbulent flow over a ridge is extended to three-dimensional topography.

202. Mayhead, G. J.
1973. Some drag coefficients for British forest trees derived from wind tunnel studies. Agric. Meteorol. 12(1):123-130.

Drag coefficients of a variety of commercial conifers 6 to 8 meters tall were determined. The drag coefficients varied within and between species, and with windspeed. Fixed drag coefficients were estimated for use in critical tree-height calculations.

203. Meroney, R. N.
1968. Characteristics of wind and turbulence in and above model forests. J. Appl. Meteorol. 7(5):780-788.

Velocity, turbulence, drag, and gaseous plume spread within a simulated canopy were measured. Several new aspects of flow at the upwind-edge of a forest are displayed.

204. Meroney, R. N.
1970. Wind tunnel studies of the air flow and gaseous plume diffusion in the leading edge of downstream regions of a model forest. Atmos. Environ. 4:597-614.

Flow in the initial fetch region results in a strikingly different streamline motion than within the equilibrium regions. Ventilation of an elevated line source into the canopy region is compared with a simple one-dimensional model.

205. Meroney, R. N., V. A. Sanborn, R. J. B. Bouwmeester, and M. A. Rider.
1976. Sites for wind power installations, wind tunnel simulation of the influence of two-dimensional ridges on windspeed and turbulence. Civil Eng. Dep., Colo. State Univ., Annu. Rep. to ERDA, ERDA/NSF/00702-75/1, 80 p. Fort Collins, Colo.

Measurements were obtained over triangular and sinusoidal shape hills of wind and turbulence. Results are compared with boundary-layer theory. Large overspeed effects over the hills were found. Separation is more pronounced on the sharp crested ridges.

206. Monahan, H. H., and M. Armendariz.
1971. Gust factor variations with height and atmospheric stability. J. Geophys. Res. 76(24):5807-5818.

An increase in gust factors occurs as instability becomes greater and as the mean wind averaging period is

enlarged. A decrease in gust factors is associated with an increase in height and windspeed and with an extension of the peak windspeed averaging interval. Tables and figures give average values of gust factors for stable and unstable conditions. Values of average peak gusts or a function of the windspeed are also given.

207. Monteith, John L.

1973. Principles of environmental physics. 241 p. Am. Elsevier Publ. Co., Inc., New York.

Momentum transfer is discussed in chapter 6, pages 78-99. Subjects covered include fetch, skin friction, form drag, and drag on leaves and trees. Wind profiles are discussed, including the behavior of the roughness length and the zero-plane displacement.

208. Mulhearn, P. J.

1977. Turbulent flow over a very rough surface. *In* Sixth Tech. Conf. Austr. Hydraul. and Fluid Mech. [Adelaide, Austr., Sec. 5-9, 1977]. p.269-272.

A wind tunnel investigation was conducted on the variation in mean velocity and Reynolds shear stress above a rough surface. The usefulness of both mean profile and eddy correlation methods for estimating fluxes above a rough terrain is discussed in light of the findings of this study.

209. Mulhearn, P. J.

1979. A note on momentum transfer above very rough surfaces. Q. J. Royal Meteorol. Soc. 105(445):721-723.

Data from wind tunnel experiments on the deviations from unity of the nondimensional velocity gradient (Ø) close to very rough surfaces are reviewed and compared with field data. It was found for $Z/Z_O < 10^2$ that Ø is less than 1 in field data and more than 1 in wind tunnel experiments. The differences are discussed in terms of roughness element flexibility and porosity.

210. Munn, R. E.

1966. Descriptive micrometeorology. 245 p. Academic Press, New York and London.

Gives a general survey of windflow (chap. 7) and turbulence (chap. 8) over homogeneous surfaces.

211. Munro, D. S., and T. R. Oke.

1975. Aerodynamic boundary-layer adjustment over a crop in neutral stability. Boundary-Layer Meteorol. 9:53-61.

An analysis of the modification of the wind profile is based on measurements at four locations extending 100 meters downwind of the leading edge of a mature wheat crop. Boundary-layer growth was rapid, but could be approximated by a four-fifths power of the fetch if a roughness factor is included. Friction velocities are also examined.

212. Myers, Vance A.

1962. Airflow on the windward side of a large ridge. J. Geophys. Res. 67(11):4267-4291.

A theoretical model is developed from which ridgeline winds are computed from data taken at the foot of the ridge. The air is treated as a compressed fluid in laminar two-dimensional flow.

213. Myers, Vance A., and George A. Lott.

1963. Three dimensional wind flow and resulting precipitation in a northern California storm. U.S. Dep. Comm. Weather Bur., Res. Pap. 44, 46 p.

Changes were made in an earlier two-dimensional windflow model by Myers for application to three-dimensional flow.

214. Nappo, C. J., Jr.

1977. Mesoscale flow over complex terrain during the eastern Tennessee trajectory experiment (ETTEX). J. Appl. Meteorol. 16(11):1186-1196.

It is shown that the horizontal averaged flow over the ETTEX region is similar to that over a rough but flat urban area, and that a surface layer of a few hundred meters thickness exists in which the influence of the large-scale topographic features was not felt. During unstable conditions, the horizontal variability of the wind is low and constant with height and tends to be independent of terrain; during stable conditions, the variability is high.

215. Norman, J. M., S. G. Perry, and H. A. Panofsky.

1976. Measurements and theory of horizontal coherence at a two-meter height. Third Symp. on Atmos. Turbulence, Diffusion, and Air Quality [Am. Meteorol. Soc., Raleigh, N.C., Oct. 19-22, 1976]. p. 26-31.

Coherence and phase delay make it possible to pick an optimum position and time delay for estimation of wind fluctuations from measurements elsewhere. An experiment was conducted to evaluate the Panofsky and Mizuno model of horizontal coherence. For unstable conditions, the results agree very well with the theory of Panofsky and Mizuno. Some problems exist under stable conditions.

216. Okulaja, F. Ola.

1968. The frequency distribution of Lagos/Ikeja wind gusts. J. Appl. Meteorol. 7(3):379-383.

The Gumbel distribution provided a good fit to the data reported. The larger the number of observations, the more closely the Gumbel theory tends to apply.

217. Oliver, H. R.

1971. Wind profiles in and above a forest canopy. Q. J. Royal Meteorol. Soc. 97(414):548-553.

For values of the Richardson number of -0.05 and +0.10, the wind profile above the canopy followed a pure log form with measured roughness length increasing linearly from 0.75 to 1.23 meters, respectively. Outside of this stability range, a log-linear profile could be fitted.

218. Oliver, H. R.

1975. Ventilation in a forest. Agric. Meteorol. 14(3): 347-355.

The form of the c[illegible] proximated by the [illegible] where U_Z a[illegible] canopy top [illegible]. [illegible] crops lies within the range of 1 to 5. Measured average wind profiles followed the theoretical form with a value of 2.5 to 3.0 irrespective of windspeed. The wind profile in the trunk space showed a bulge under lapse conditions.

219. Oliver, H. R.

1975. Wind speeds within the trunk space of a pine forest. Q. J. Royal Meteorol. Soc. 101:167-168.

Observations show large and frequent fluctuations in windspeed and direction below the canopy. Because the windspeed bulge in the trunk space is found to increase with increasing instability, it seems likely that it may be associated with convective activity.

220. Oliver, H. R., and G. J. Mayhead.

1974. Wind measurement in a pine forest during a destructive gale. Forestry 47(2):185-194.

Wind gusts at top of the canopy during the gale attained 17.5 m/sec. Wind profiles agreed well with the theoretical logarithmic profile above the canopy and the exponential profile below. During the gale, the zero-plane displacement and roughness length values were similar to those at lower speeds. The windspeeds that blew trees down were much lower than those predicted.

221. Orgill, M. M.

1977. Survey of wind measurement field programs. Battelle Pac. Northwest Lab., NNWL Wind-3 UC-60, 53 p. Richland, Wash.

The report identifies and briefly summarizes 139 field programs that have used wind networks. In general, the studies were mesoscale in areal extent. The time period covered is from 1940 to 1977.

222. Orville, Harold D.

1964. On mountain upslope winds. J. Atmos. Sci. 21(6):622-633.

Equations for a two-dimensional thermal initiation problem are used in a numerical study of upslope winds. Two cases are considered, one in a neutral environment, the second in a slightly stable environment. Many of the features of the upslope wind are reproduced in the model.

223. Pandolfo, Joseph P.

1966. Wind and temperature profiles for constant-flux atmospheric boundary layer in lapse conditions with a variable eddy conductivity to eddy viscosity ratio. J. Atmos. Sci. 23(5):495-502.

A set of wind and temperature profile formulas is derived for the constant-flux atmospheric boundary layer in lapse stratification. The derived free-convection wind profile is found to be more consistent with observed wind profiles than other theoretical profiles. Some practical aspects of the use of the profile laws are discussed.

224. Panofsky, H. A.

1963. Determination of stress from wind and temperature measurements. Q. J. Royal Meteorol. Soc. 89(379):85-94.

A form of the diabatic wind profile is used to estimate surface stress from measured winds and temperatures. Excellent estimates of stress can be made, given the roughness length, an estimate of the Richardson number, and an accurate wind measurement at one level.

225. Panofsky, H. A., R. Lipshutz, and J. Norman.

1979. On characteristics of wind direction fluctuations in the surface layer. *In* Fourth Symp. on Turbulence, Diffusion, and Air Pollution of the Am. Meteorol. Soc. [Reno, Nev., Jan. 15-18, 1979]. p. 1-4.

Wind fluctuations over rolling terrain are compared to ...er flat and uniform terrain. Measurements were ...eters above ground with very few exceptions. The ... standard deviation of wind fluctuations to the ...ver flat terrain than over rolling terrain.

... Sullivan, D. W. Thomson, and

...d fluctuations ...n Probability ...nce [Boulder, Colo., June 19-22, 1973]. p. 274-276. Am. Meteorol. Soc.

Preliminary measurements of the coherence decay parameter have verified a theoretical hypothesis relating the decay parameter to the level of turbulence. Studies of the predicted and observed phase differences suggest that eddies larger in scale than the surface-to-anemometer height are translated at a velocity slightly greater than that of the mean windspeed.

227. Panofsky, H. A., and A. A. Townsend.

1964. Change of terrain roughness and the wind profile. Q. J. Royal Meteorol. Soc. 90(384):147-155.

The authors theorize that only the air below an internal boundary is affected by a terrain roughness change and that the air above the boundary is still moving with the speed and stress that it had upwind of the change. A fairly sharp boundary separates the air and, for micrometeorological distances, the slope of the interface is of the order of 1/10.

228. Pendergast, M. M., and T. V. Cawford.

1974. Actual standard deviations of vertical and horizontal wind direction compared to estimates from other measurements. *In* Symp. on Atmos. Diffusion and Air Pollution of the Am. Meteorol. Soc. [cosponsored by the World Meteorol. Organ., Santa Barbara, Calif., Sept. 9-13, 1974]. p. 1-6.

Meteorological data collected near the Savannah River in South Carolina were used to assess the applicability of several techniques to determine horizontal and vertical wind fluctuations. The errors caused by the use of a temperature profile are greater than those involved in calculating the standard deviation of fluctuations directly from measurements of the fluctuation angles.

229. Perrier, E. R., J. M. Robertson, R. J. Millington, and D. B. Peters.

1972. Spatial and temporal variation of wind above and within a soybean canopy. Agric. Meteorol. 10(6):421-442.

Wind profile measurements within the crop canopy are consistent with a two-dimensional flow field. The turbulent length scale describes the long, thin types of "eddies" flowing within the turbulent boundary layer above the crop canopy. The probability distributions of wind velocity were largely non-Gaussian.

230. Perry, Steve G., John M. Norman, Hans. A. Panofsky, and J. David Martsolf.

1978. Horizontal coherence decay near large mesoscale variations in topography. J. Atmos. Sci. 35(10):1884-1889.

Measurements of turbulence were made at 2 meters above the surface. A good correlation has been found between the variance spectrum of the lateral (crosswind) velocity component and an estimate of the lateral Eulerian scale of the longitudinal velocity component. The present data compare favorably with an earlier theoretical model.

231. Peterson, Ernest W., and Neils E. Busch.

1978. The effect of local terrain irregularities on the mean wind and turbulence characteristics near the ground. *In* WMO Symp. on Boundary Layer Physics Applied to Specific Problems of

Air Pollution [Norrköping, June 19-23), 1978]. WMO - No. 510, p. 45-50. World Meteorol. Organ., Geneva.

This paper presents a review of findings of a field program conducted at Risø, Denmark, to test models of airflow over a change in surface roughness.

232. Peterson, Ernest W., Niels Otto Jensen, and Jørgen Hostrup.

1979. Observations of downwind development of windspeed and variance profiles at Bognaes and comparison with theory. Q. J. Royal Meteorol. Soc. 105(445):521-529.

Observations of atmospheric flow over a change in surface roughness are reported. Both windspeed and turbulence were measured. It was found that the predictions of second-order closure models are consistent with the observed flow.

233. Peterson, Ernest W., Leif Kristensen, and Chang-Chun Su.

1976. Some observations and analysis of wind over non-uniform terrain. Q. J. Royal Meteorol. Soc. 102(434):857-869.

Wind measurements were made from the surface to a height of 12 meters over a distance of 150 meters. The variation in the elevation of the underlying terrain has a larger effect than that of the variation in surface roughness. The shape of the downwind profile is consistent with the prediction of the second-order closure change of roughness models.

234. Petit, C., M. Trinite, and P. Valentin.

1976. Study of turbulence diffusion above and within a forest - application in the case of SO_2. Atmos. Environ. 10(12):1057-1063.

Some results concerning characteristics of airflow within and above a forest are presented. These include horizontal mean windspeed profiles, turbulent intensities, turbulent transfer coefficients, autocorrelation curves, energy spectra, turbulent scales, and microscales.

235. Petkovsek, Z., and H. Hocevar.

1971. Night drainage winds. Arch. Met. Geoph. Biokl. Serv. A, 20:353-360. [In English.]

Presents a model of drainage winds given wind velocity as a function of the following parameters: net radiation, friction coefficients, slope, and environmental lapse rate.

236. Petkovsek, Z., and M. Ribaric.

1965. On the airflow over mountains with gentle slopes. Tellus 17(4):443-448.

Nonlinear equations for the two-dimensional, small-scale, steady-state flow of a compressible fluid are put in a form appropriate for the treatment of streamlines with gentle slopes. The equations are solved numerically and examples are given to demonstrate the difference between solutions obtained by linearized and nonlinearized models.

237. Petzold, D. E., and S. Kelly.

1975. The effect of woodland and elevation on winds in the Schefferville area. McGill Univ., Dep. Geophys., Climatol. Bull. 18, 18 p. Montreal, Can.

Wind measurements were made at eight different sites varying in elevation and exposure. A linear relationship exists between each site and a reference site. To account for the modifying effect of vegetation, and empirical density number was used depending upon the presence of a tree barrier or a few shrubs, and for a dense cover of shrubs. The barrier effect and the effect of elevation on wind at particular sites is discussed.

238. Plate, Erich J.

1971. Aerodynamic characteristics of atmospheric boundary layers. 190 p. U.S. Atomic Energy Comm., Div. Tech. Infor. Oak Ridge, Tenn.

This report presents a summary of mean-flow conditions in the planetary boundary layers.

239. Plate, Erich J.

1971. The aerodynamics of shelter belts. Agric. Meteorol. 8(3):203-222.

How the interaction of aerodynamic factors shapes the velocity distribution in the shelter region is discussed qualitatively. Emphasis is on the region directly downwind from the shelter. Some conclusions are drawn to research needs for improving the understanding of shelter belts aerodynamics.

240. Plate, Erich J., and A. A. Quaraishi.

1965. Modeling of velocity distributions inside and above tall crops. J. Appl. Meteorol. 4(3):400-408.

A model crop consisting of flexible plastic strips was investigated by means of a low-speed wind tunnel. Results indicate that some distance (X_O) downstream from the edge of the model crop, wind profiles in and above the crop reach an equilibrium state. The length X_O is discussed. Results are compared with field studies.

241. Pockels, F.

1901. The theory of the formation of precipitation on mountain slopes. Mon. Weather Rev. 21:152-159. [Transl. from Ann. d. Physik, 1901(4), vol. III, p. 459-480.]

A theory of inviscid flow over mountainous terrain is discussed. Solutions to velocity potential equations are found considering a series of assumptions. Streamline flow is used to specify the contour of the ground. An example of flow over an idealized mountain range is given.

242. Pooler, F., Jr.

1963. Airflow over a city in terrain of moderate relief. J. Appl. Meteorol. 2(4):446-456.

The flow during stable hours appeared to be approximately antitriptic. The pressure forces consisted of both large-scale and local components. Flo[illegible] removed from surface frictio[illegible] oscillation about the g[illegible] particular [illegible] the large[illegible] topographic barriers to the flow.

243. Poppendiek, H. F.

1951. Gustiness profiles in the lower layers of the atmosphere. *In* On atmospheric pollution. Meteorol. Monogr. 1(4):36-38.

Two sets of gustiness profiles in the lower layers of the atmosphere under a range of stability conditions are presented. One set was obtained over an Arizona desert and the other over Los Angeles. Some interpretations of the diurnal variation of the gustiness are given.

244. Ramsdell, J. V.

1978. Estimates of the number of large amplitude gusts. Battelle Pac. Northwest Labs, PNL-2508, 44 p. Richland, Wash.

The number of large amplitude gusts per year is treated as a function of the annual mean windspeed and terrain roughness. The treatment is based upon the assumption that the atmosphere has neutral stability during high winds. Results are presented in tabular form as a function of gust amplitudes and hourly average windspeed.

245. Ramsdell, J. V.

1978. Wind shear fluctuations downwind of large surface roughness elements. J. Appl. Meteorol. 17(4):436-443.

Wind shear fluctuations are described by a Pearson Type IV probability distribution. Models are presented for the standard deviation, skewness, and kurtosis of the distributions.

246. Randall, J. M.

1969. Wind profiles in an orchard plantation. Agric. Meteorol. 6(6):439-452.

Vertical wind profiles between 6 and 40 feet height were obtained in an orchard with trees of crown diameter 13 feet; height, 12 feet; and spacing of 24 feet. The horizontal attenuation of wind was large for the first three to four tree rows beyond which a linear decrease of wind was observed. Vertical wind profiles were fitted to a logarithmic profile. No significant relationship between profile parameters and atmospheric stability was found.

247. Rao, K. S., J. C. Wyngaard, and O. R. Cote'.

1974. The structure of the two-dimensional internal boundary layer over a sudden change of surface roughness. J. Atmos. Sci. 31(3):738-746.

The effects of an abrupt change of surface roughness in the mean flow are investigated by means of a closed system of equations together with specified boundary conditions. The distributions of wind shear, mixing length scales, and ratio of stress to turbulent kinetic energy are shown to differ significantly from their equilibrium flow variations.

248. Rauner, Ju. L.

1976. Deciduous forest. *In* Vegetation and the atmosphere, vol. 2. Case studies. Chap 8, p. 241-264. S. L. Monteith, ed. Academic Press, New York, London.

The essential characteristics of the micrometeorological regime of deciduous forests are presented including the aerodynamic characteristics of leaf canopies.

249. Raupach, M. R.

1979. Anomalies in flux-gradient relationships over forest. Boundary-Layer Meteorol. 16(4):467-486.

Results show that the values of vertical turbulent diffusivity momentum (K_M) over a forest are not significantly different from those predicted by semiempirical diabatic
ɘ functions appropriate to smoother surfaces
-hort grass. However, the values for heat (K_H)
vapor transfer (K_E) exceed their predicted
n average factor of 2. Methods are given to
nd K_E anomalies.

and temperature structure in a
nd a contiguous field. For.

l are presented.
ıeights and five
ırest and at four

heights in a nearby field. Data were classified with respect to wind direction relative to the forest edge, windspeed, gustiness, and cloudiness. At the forest edge, windspeed in the trunk space was greater than in the canopy for a distance of about 60 meters. With a longer fetch through the forest, speeds varied little with height to midcanopy.

251. Read, Ralph A.

1964. Tree windbreaks for the central Great Plains. USDA For. Serv. Agric. Handb. 250, 68 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

The effects of tree height, density, barrier width, and wind velocity are given. Many figures illustrate the windbreak effect. The barrier shown in figure 5, p. 5, is wide enough (15 tree heights) to use the data to estimate the sheltering effect downwind of the lee edge of a forest.

252. Reed, Jack W.

1978. Windspeed distribution changes with height at selected weather stations. Sandia Laboratories, SAND 76-0714, 54 p. Albuquerque, N. Mex.

Ten-year records of hourly windspeed observations at 15 selected weather stations are presented. Windspeed distribution curves and tables of synthesized time series have been prepared.

253. Reifsnyder, William E.

1955. Wind profiles in a small isolated forest stand. For. Sci. 1(4):289-297.

A fully developed "infinite stand" profile probably occurred at 250 feet from the forest edge under lapse conditions. Under inversion conditions, the wind profile reached its full development nearer the edge. Maximum attenuation of wind by tree crowns was 50 to 60 percent during lapse conditions and 60 to 70 percent during inversion conditions. Greater percent reduction occurred with stronger winds.

254. Rider, Laurence J.

1966. Low-level jet at White Stands Missile Range. J. Appl. Meteorol. 5(3):283-287.

A low-level wind maximum frequently observed at White Sands is often supergeostrophic and associated with large values of wind shear. The jet is predominantly a nocturnal phenomenon with the nose of the profile usually near the height of the nocturnal temperature inversion. There were cases in which a temperature inversion developed during the night, but a significant low-level wind maximum was not evident.

255. Roth, Rainer.

1971. Turbulence spectra with two separated regions of production. J. Appl. Meteorol. 10(3):430-432.

The observed spectra of turbulent energy in forests and the free atmosphere show a "hump" that may be explained by a process producing energy in a region where existing turbulent energy, produced at lower wavelengths, is cascaded.

256. Rutter, N.

1968. Geomorphic and tree shelter in relation to surface wind conditions, weather, time of day and season. Agric. Meteorol. 5(5):319-334.

Mean hourly windspeeds at 4 feet height on 15 sites in varying topography were recorded for a year. Results show how physical factors affect wind exposure and allow some general conclusions on geomorphic shelter.

257. Ryan, Bill C.

1977. A mathematical model for diagnosis and prediction of surface wind in mountainous terrain. J. Appl. Meteorol. 16(6):571-584.

A model was developed on the premise that mountain winds are the result of vector addition of different wind components. The components include valley-mountain wind, slope wind, sea-land breeze, larger scale wind, and sheltering and diverting effect of topography. Model-generated winds are compared to observed winds.

258. Ryan, Bill C., and J. Gregory Brown.

1978. Influences on wind in mountainous terrain. *In* Conf. on Sierra Nevada Meteorology [sponsored by the Am. Meteorol. Soc. and the USDA For. Serv., South Lake Tahoe, Calif., June 19-21, 1978]. p. 46-52.

Analysis of daytime and nighttime winds obtained at eight stations during summer months shows that the winds tend to switch directions from day to night in mountains. The reversal may not be 180 degrees, but depends upon canyon conditions.

259. Sacre', C.

1979. An experimental study of the airflow over a hill in the atmospheric boundary layer. Boundary-Layer meteorol. 17(3):381-401.

Wind measurements were obtained along the slope of a 100-meter high hill with an average slope of 8 percent. Near the ground, local topographic effects and inhomogeneous roughness along the slope have the same effect as the mean slope of the hill. The overspeed is proportional to the upwind slope, but the turbulent structure does not seem to be disturbed by the hill.

260. Sadeh, Willy Z.

1975. Simulation of flow above forest canopies. *In* Heat and mass transfer in the biosphere, part I. Transfer processes in the plant environment. p. 251-263. D. A. deVries and N. H. Afgan, eds. Scripta Book Co., Washington, D.C.; John Wiley & Sons, New York.

The similarity criteria for achievement of wind-tunnel simulation of forest canopy flow are discussed. A forest canopy model was used to investigate upper-canopy flow. Mean velocity distributions are presented.

261. Sadeh, W. Z., J. E. Cermak, and T. Kawatani.

1971. Flow over high roughness elements. Boundary-Layer Meteorol. 1:321-344.

The results of a wind tunnel model study indicate that the flow may be divided into transition and fully developed regions, followed by a short adjustment near the downstream terminus of a rough boundary. The transition region has a strong effect in the flow characteristics within and above the layer of roughness elements. Generally, the roughness zone influence extends to more than three times the roughness height.

262. Sauer, Fred M., Wallace L. Fons, and Keith Arnold.

1951. Experimental investigation of aerodynamic drag in tree crowns exposed to steady wind-conifers. 19 p., mimeo. USDA For. Serv., Div. For. Fire Res., Washington, D.C.

The analysis of wind tunnel and field work is given. Variation of tree crown drag was due primarily to bending which results from the application of drag forces. Data were reduced to a set of dimensionless functional relationships that are different for each species tested; however, the general characteristics are the same.

263. Scholtz, M. T., and C. J. Brouckaert.

1978. Modeling of stable air flow over a complex region. J. Appl. Meteorol. 17(9):1249-1257.

A linear model is achieved by assuming the coupling between the motion of surface air and the overlying geostrophic wind is through a pressure gradient. The two-dimensional, steady state, potential flow model takes into account the land breeze, slope and valley, and synoptic-scale pressure gradient.

264. Schroeder, Mark J.

1960. Exploratory fire climate surveys on prescribed burns. Mon. Weather Rev. 88(4):123-129.

Local wind patterns, which are extremely complex, appear to be made up of several circulations of different size scales. Results include finding an increase of wind blowing out of a lee side of a fire and a down-canyon afternoon wind. Actual fire behavior was close to that indicated by the observed wind patterns.

265. Schroeder, Mark J., and Charles C. Buck.

1970. Fire weather -- a guide for application of meteorological information to forest fire control operations. USDA For. Serv. Agric. Handb. 360,229 p. (reprinted 1977). U.S. Gov. Print. Off., Washington, D.C.

A descriptive, illustrative discussion of the weather factors related to fire control planning and action. Surface wind is covered in chapter 6 (general winds) and chapter 7 (convective winds). The use of technical terms is kept to a minimum.

266. Scorer, R. S.

1956. Airflow over an isolated hill. Q. J. Royal Meteorol. Soc. 82:75-81.

The perturbation theory is used to compute the vertical displacement of a uniform airstream passing over a solitary hill of circular and oval shape. Diagrams show contours of the vertical displacement at four different heights above the theoretical hills.

267. Seginer, I., and P. J. Mulhearn.

1978. A note on vertical coherence of streamwise turbulence inside and above a model plant canopy. Boundary-Layer Meteorol. 14(4):515-523.

Measurements of longitu
were made inside ar
tunnel. It was fo
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similar in n
tions appea

268. Shaw,

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sional verti
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269. Shaw, R. H., R. H. Silversides, and G. W. Thurtell.
1974. Some observations of turbulence and turbulent transport within and above plant canopies. Boundary-Layer Meteorol. 5(4):429-449.

Shear stress was measured directly within a vegetation canopy. The power spectra of velocity above a forest canopy obeyed a -5/3 power relation. Isotropy was present above a pine forest.

270. Shaw, Roger H., David P. Ward, and Donald E. Aylor.
1979. Frequency of occurrence of fast gusts of wind inside a corn canopy J. Appl. Meteorol. 18(2): 167-171.

A probability density distribution of the total wind and of the change in windspeed were determined. Gusts of wind with speeds exceeding the local mean wind by a factor of 3 or more were frequent near the middle of the canopy.

271. Sherlock, R. H.
1951. Analyzing winds for frequency and duration. *In* On atmospheric pollution. Meteorol. Monogr. 1(4):42-49.

A means is devised to estimate the frequency and duration of future winds above critical values at a given site.

272. Sherlock, R. H.
1953. Variations of wind velocity and gusts with height. Am. Soc. Civil Eng. Trans. 118:463-488.

Airflow over level open country is considered. The 1/7 power law is a sufficiently close approximation to the variation of wind velocity up to 1,000 feet, above which a constant velocity is justified. Gust factors are proportional to the inverse ratio of height raised to the 0.0625 power.

273. Sherman, Christine A.
1978. A mass-consistent model for wind fields over complex terrain. J. Appl. Meteorol. 17(3):312-319.

A model was developed where interpolated three-dimensional mean winds were adjusted in a weighted least-squares sense to satisfy continuity. The upper and lateral boundaries above topography were assumed to be open air; the bottom boundary was determined by the topographic elevations of the area studied.

274. Shinn, Joseph Hancock.
1971. Steady state two-dimensional air flow in forests and the disturbance of surface layer flow by a forest wall. Ph.D. thesis. Univ. Wis., Madison. 91 p.

The study provides models of the mean momentum transport processes in and above forests, for the equilibrium flow in forests, and for the nonequilibrium airflow in the transition region. The study is confined to neutral stability conditions.

275. Shir, C. C.
1972. A numerical computation of air flow over a sudden change of surface roughness. J. Atmos. Sci. 29(2):304-310.

A set of equations governing flow over a roughness change is solved by a finite-difference method. A turbulent energy equation is included. Two boundary layers; a velocity layer and a stress layer, are found.

276. Shukla, J., and K. R. Saha.
1974. Computation of non-divergent streamfunction and irrotational velocity potential from the observed winds. Mon. Weather Rev. 102(6): 419-425.

An iterative scheme is presented to compute the stream function and velocity potential. A wind field can be reconstructed from the computed fields of stream function and velocity potential.

277. Sigl, Arden B., Ross B. Corotis, and Danny J. Won.
1979. Run duration analysis of surface wind speeds for wind energy application. J. Appl. Meteorol. 18(2):156-166.

A model is developed for distribution of windspeed persistence above and below fixed reference speeds. It is possible to interpret the model in terms of a single parameter that can be calibrated from the mean seasonal windspeed at a site.

278. Simard, A. J.
1971. Calibration of surface wind observations in Canada. For. Fire Res. Inst., Inf. Rep. FF-X-30, 19 p. Ottawa, Ont.

A procedure is outlined whereby surface observations can be used to obtain area averages. A map showing windspeeds across Canada, which can be used to calibrate any station, is also presented.

279. Singer, Irving A., and Maynard E. Smith.
1953. Relation of gustiness to other meteorological parameters. J. Meteorol. 10:121-126.

A gustiness classification is defined by the range and appearance of the horizontal wind direction trace. Seasonal and diurnal variations are presented.

280. Skibin, D.
1974. Variation of lateral gustiness with windspeed. J. Appl. Meteorol. 13(6):654-657.

Observations show a decreasing trend of lateral direction fluctuations with increasing windspeed above 2 miles per second. For low windspeeds (less than 2mi/sec), direction fluctuations increased with increasing windspeed durin stable and unstable conditions.

281. Slade, David H., ed.
1968. Meteorology and atomic energy 1968. 445 p. U.S. Atomic Energy Comm./Div. Tech. Inf., Oak Ridge, Tenn.

Some basic principles of meteorology are presented including the local wind structure. Includes textbook knowledge as well as handbook type aids in the form of equations and graphs.

282. Slade, David H.
1969. Wind measurements on a tall tower in rough and inhomogeneous terrain. J. Appl. Meteorol. 8(2):293-297.

Windspeed profiles and the standard deviation of the horizontal wind direction distribution at an irregular site differ quite radically depending on the local upwind terrain.

283. Small, R. T.
1957. The relationship of weather factors to the rate of spread of the Robie Creek fire. Mon. Weather Rev. 85(1):1-8.

On four of five days, the fire followed patterns previously recognized as being usually associated with prevailing weather conditions. One of those days was an example of a long fire run resulting from a strong and persistent horizontal wind.

284. Smedman-Hogstrom, Ann-Sofi, and Ulf Hogstrom.
1978. A practical method for determining wind frequency distributions for the lowest 200 m. from routine meteorological data. J. Appl. Meteorol. 17(7):942-954.
A model is used to calculate the rate of growth of internal boundary layers resulting from discontinuities in roughness as well as the shape of the wind profile in various layers. Shape characteristics of the profile are determined as a function of roughness length and stability.
285. Smith, F. B., and P. F. Abbott.
1961. Statistics of lateral gustiness at 16 m. above ground. Q. J. Royal Meteorol. Soc. 87(374):549-561.
Many wind observations were obtained. The hourly average values of the standard deviation of wind fluctuations ($\alpha_{\varnothing}$) are classified according to windspeed and stability. A critical value of stability is indicated for which $\alpha_{\varnothing}$ depends either on stability or the windspeed. Tables and figures giving values of $\alpha_{\varnothing}$ as a function of stability and wind for various sampling periods are presented.
286. Smith, F. B., D. J. Carson, and H. R. Oliver.
1972. Mean wind-direction shear through a forest canopy. Boundary-Layer Meteorol. 3(2):178-190.
The equations of motion applying to the wind field in a forest canopy are simplified to a balance between the shearing stress gradient and either the form-drag of the leaves in the upper dense canopy or the overall horizontal pressure gradient in the more open space beneath. Results indicate that, in descending through the forest, the stress and wind vectors turn through an angle that depends on the forest characteristics and on the stability and the speed of the airflow above the forest.
287. Smith, Maynard E.
1951. The forecasting of micrometeorological variables. *In* On atmospheric pollution. Meteorol. Monogr. 1(4):50-55.
A forecasting program for the Brookhaven National Laboratory is discussed in some detail. The technique is based on empirical relationships between synoptic and micrometeorological variables. Considerable attention is given to the classification and prediction of horizontal gustiness.
288. Sommers, William T.
1976. On the relationship between LFM predictions, on site rawinsonde observations and surface flow in mountainous terrain. *In* Sixth Conf. on Weather Forecasting and Analysis [Albany, N.Y., May 10-14]. p. 141-145. Am. Meteorol. Soc., Boston, Mass.
The limited fine mesh (LFM) forecasts by the National Weather Service can predict synoptic scale forcing of the boundary-layer and surface flow with acceptable accuracy in mountainous terrain.
289. Stanhill, G.
1969. A simple instrument for the field measurement of turbulent diffusion flux. J. Appl. Meteorol. 8(4):509-513.
The relationship between the zero-plane displacement (d) and vegetation height (h) is given. The results agree completely with the relationship d = 0.64h derived earlier by Cowan.
290. Sterns, Charles R., and Heinz H. Lettau.
1963. Report on two wind profile modification experiments in air flow over the ice of Lake Mendola. *In* Studies of the effect of variations in boundary conditions on the atmospheric boundary layer. p. 115-138. Univ. Wis., Madison, Dep. Meteorol., Annu. Rep. 1963.
Two different wind profile modification experiments, employing an array of conifer saplings (Christmas trees) and bushel baskets, were made in late winter. An analysis of the results is presented in terms of horizontal momentum budgets as a function of wind fetch across and downwind of the obstacles.
291. Stewart, Dorathy A., and Osker M. Essenwanger.
1978. Frequency distribution of wind speed near the surface. J. Appl. Meteorol. 17(11):1633-1642.
The Weibull distribution provides a good analytical approximation to the cumulative distribution. Two methods of fitting a Weibull distribution with a nonzero location parameter are discussed. The three-parameter model is better than the two-parameter model for predicting extreme values.
292. Sutton, O. G.
1953. Micrometeorology: a study of physical processes in the lowest layers of the earth's atmosphere. 333 p. McGraw-Hill Book Co., Inc., New York, London.
A basic text of micrometeorological processes including fluid flow and the problems of wind structure near the earth's surface.
293. Swanson, R. N., and H. E. Cramer.
1965. A study of lateral and longitudinal intensities of turbulence. J. Appl. Meteorol. 4(3):409-417.
The lateral and longitudinal intensities decrease with height in all thermal stratification that can be expressed in terms of a power law. The turbulent intensity at all heights tends to be universally proportional to the mean wind. Tables and figures showing values of the standard deviation of wind direction as a function of height, stratification, and windspeed are given.
294. Szeicz, G., D. E. Petzold, and R. G. Wilson.
1979. Wind in the subarctic forest. J. Appl. Meteorol. 18:1268-1274.
Windspeeds were measured at 2 - mile height in open lichen woodlands and were related to standard winds recorded at a local airport site. The reduction in wind is related to tree height, stand density, and shrub cover.
295. Tajchman, S. J.
1973. On vertical velocity profiles of meteorological parameters above a layer of rough vegetation. J. Geophys. Res. 78(27):6381-6385.
Profiles of windspeed and other parameters were measured above a pine forest. In addition to possible practical applications, the Monin-Obukhov formulas can be used to interpret the meteorological processes.
296. Takle, E. S., and J. M. Brown.
1978. Note on the use of Weibull statistics to characterize windspeed data. J. Appl. Meteorol. 17(4):556-559.
A hybrid density function is given for describing windspeed distribution having nonzero probability of calm. A Weibull probability graph is used to determine distribution parameters.

297. Tattleman, Paul.
1975. Surface gustiness and windspeed range as a function of time interval and mean windspeed. J. Appl. Meteorol. 14(7):1271-1276.

The gust factor (peak wind divided by the steady wind) can be used to describe the relationship between mean windspeed and windspeed range for a specific interval of time. Results are applicable to smooth locations at a height of approximately 15 meters above the surface.

298. Taylor, Dee F., and Dansy T. Williams.
1967. Meteorological conditions of the Hellgate fire. USDA For. Serv. Res. Pap. SE-29, 12 p. Southeast. For. and Range Exp. Stn., Asheville, N.C.

High temperatures, low humidities, and strong winds produced a condition of extreme fire danger. Large-scale negative divergence and positive vorticity of the surface wind occurred. These favored intensification of the fire.

299. Taylor, P. A.
1969. On planetary boundary layer flow under conditions of neutral thermal stability. J. Atmos. Sci. 26(3):427-431.

A wind spiral model is used to represent the flow above a surface of uniform roughness. Test of the model is inconclusive, perhaps due to surface inhomogeneity.

300. Taylor, P. A.
1969. The planetary boundary layer above a change in surface roughness. J. Atmos. Sci. 26(3):432-440.

A mixing length model is used to study turbulent airflow under conditions of neutral stability. Numerical solutions are given to a parabolic system of partial differential equations. The case of flow above a step change in surface roughness is solved. A very long fetch is required for equilibrium flow to exist above the new surface. In particular, surface wind direction adjusts very slowly.

301. Taylor, P. A.
1970. A model of airflow above changes in surface heat flux, temperature and roughness for neutral and unstable conditions. Boundary-Layer Meteorol. 1(1):18-39.

Results indicate large increases in shear stress at the outer boundary of the internal boundary layer for airflow with neutral upstream conditions encountering a step change in surface temperature with no roughness change. Other situations are investigated.

302. Taylor, P. A.
1977. Numerical studies of neutrally stratified planetary boundary-layer flow above gentle topography. Boundary-Layer Meteorol. 12(1):37-60.

A numerical model of flow above two-dimensional gentle topography is developed. Comparisons are made with surface predictions for flow over Gaussian hills. The flow at various angles above hills, valleys, and escarpments is modeled.

303. Tennekes, H.
1973. The logarithmic wind profile. J. Atmos. Sci. 30(2):234-238.

This paper explores the practical consequences of the asymptotic nature of the logarithmic wind profile in the planetary boundary layer. The value of the von Karman constant of 0.35 ± 0.02 is recommended for micrometeorological application over a smooth terrain.

304. Thom, A. S.
1968. The exchange of momentum, mass, and heat between an artificial leaf and the airflow in a wind tunnel. Q. J. Royal Meteorol. Soc. 94(399):44-55.

The coefficients C_d (momentum), C_v (mass), and C_h (heat) were determined from measurements. A generalized transfer coefficient (C_o) for mass or heat is given. C_o was shown to be proportional to (windspeed) to the minus one-half power in a regime of fully forced convection.

305. Thom, A. S.
1971. Momentum absorption by vegetation. Q. J. Royal Meteorol. Soc. 97(414):414-428.

Measurements were made in a wind tunnel of drag on elements of an artificial crop and of wind profiles above and within the crop. Values are obtained of the eddy viscosity, roughness parameters, and the von Karman constant. Wind profiles are discussed.

306. Thom, A. S.
1975. Momentum, mass, and heat exchange of plant communities. *In* Vegetation and the atmosphere, vol. 1. Principles. Chap. 3, p. 57-109. J. L. Monteith, ed. Academic Press, London, New York.

A discussion of basic principles of some meteorological processes associated with vegetation is presented. The log-wind profile is discussed along with the transfer coefficients including drag forces and eddy motion.

307. Thompson, N.
1979. Turbulence measurements above a pine forest. Boundary-Layer Meteorol. 16(3):293-310.

Measurements in neutral stability confirmed the validity of the aerodynamic method of estimating momentum fluxes above the canopy. In stable conditions, a log-linear wind profile provided a good fit to data. Spectra in unstable conditions were generally more sharply peaked than those over smoother terrain.

308. Thompson, Roger S.
1978. Note on the aerodynamic roughness length for complex terrain. J. Appl. Meteorol. 17:1402-1403.

Field data are presented that demonstrate the application of a logarithmic windspeed profile over complex terrain.

309. Thuillier, R. H., and V. O. Lappe
1964. Wind and temperature profile characteristics from observations on a 1400 ft tower. J. Appl. Meteorol. 3(3):299-306.

Observed windspeed profiles are analyzed to determine the relationship to lapse rate structure. The wind profile can be divided into inversion and noninversion profiles. For adiabatic conditions, the logarithmic wind law represents the data well to a height of 300 to 400 feet. Above this height, the windspeed is nearly constant. The more stable wind profiles are represented with a power law.

310. Tomlinson, A. I.
1975. Structure of wind over New Zealand. Tech. Inf. Circ. 147 (rev. of Tech. Inf. Circ. 144 by J. F. de Lisle), 24 p. New Zealand Meteorol. Serv., Wellington.

The measurement and nature of the surface wind, including the effect of topography and underlying surface,

are discussed. The ratio of the maximum gust to the 10-minute mean wind is given for several stations. The mean hourly windspeed is represented by a Weibull distribution.

311. Turner, J. A.
1968. Standard deviation of wind direction estimated from direct observation of a sensitive wind vane. J. Appl. Meteorol. 7(4):714-715.

Wind gustiness was found by direct observation of fluctuations of a lightweight sensitive wind vane.

312. Tyson, P. D.
1968. Velocity fluctuations in the mountain wind. J. Atmos. Sci. 25(3):381-384.

The maximum turbulent energy is generated by waves of the order of 10 km in length and a period of 1 hour which fills the spectral gap between purely micrometeorological fluctuations and those of mesometeorological origin.

313. Van Der Hoven, Isaac.
1957. Power spectrum of horizontal windspeed in the frequency range from 0.0007 to 900 cycles per hour. J. Meteorol. 14(2):160-164.

There appear to be two major eddy-energy peaks in the power spectrum of horizontal wind. One peak occurs at a period of 4 days and a second peak at a period of 1 minute. Between the two peaks, a broad spectral gap is centered at a frequency ranging from 1 to 10 cycles per hour. The spectral gap seems to exist under varying terrain and synoptic conditions.

314. Van Hylckama, T. E. A.
1970. Winds over saltcedar. Agric. Meteorol. 7(3):217-233.

In 90 percent of the cases, the wind profiles above the stand can be represented by the logarithmic wind law. There was considerable turbulence within the saltcedar thicket.

315. Vukovich, Fred M., and Andrew Clayton.
1977. On a technique to determine wind statistics in remote locations. U.S. Dep. Energy, Div. Solar Energy, Final Rep. RLO-2445-781, 108 p.

A wind production technique uses historical wind data from a synoptic weather station together with a statistical prediction model to obtain data from which wind statistics in remote locations can be developed. The form of the statistical model and the parameter estimates were determined using simulations based on a hydrodynamic model. Predictions were made in and around the city of St. Louis.

316. Webb, E. K.
1970. Profile relationships: the log-linear range, and extension to strong stability. Q. J. Royal Meteorol. Soc. 96:67-90.

The diabatic profile in the surface layer was studied by applying analysis methods to data from O'Neil, U.S.A., and from Australia. It was found that the log-linear law is valid over a small range of unstable and a wide range of stable conditions.

317. Widger, William K., Jr.
1977. Estimations of windspeed frequency distributions using only the monthly average and fastest mile data. J. Appl. Meteorol. 16(3):244-247.

Average windspeed frequency distributions appear to be adequately approximated based on only the monthly average and fastest mile data. The method is based on a square-root transformation of the speeds to an approximately normal distribution.

318. Wieringa, J.
1973. Gust factors over open water and built-up country. Boundary-Layer Meteorol. 3(4):424-441.

A simple, nonspectral model for gustiness at high windspeeds in the constant shear layer is proposed and checked. The model relates gustiness to surface roughness and height above the surface for gust wavelengths of about 200 meters. Data are presented for gust factors on a lake and at the edge of a town.

319. Wieringa, J.
1976. An objective exposure correction method for average windspeeds measured at a sheltered location. Q. J. Royal Meteorol. Soc. 102(431): 241-253.

A gust factor model is used to correct for sheltering effects caused by small-scale obstacles. The actual duration of the recorded maximum gusts can be obtained from instrumentation response specifications.

320. Wilson, N. Robert, and Roger H. Shaw.
1977. A higher order closure model for canopy flow. J. Appl. Meteorol. 16(11):1197-1205.

A one-dimensional model of canopy airflow was developed with closure achieved by parameterizing higher order terms. The closure scheme relies upon a prescribed length scale. The model predicts mean wind velocity, Reynolds stress, and turbulent intensities from the soil surface to twice the canopy height.

321. Wood, D. H.
1978. Calculation of the neutral wind profile following a large step change in surface roughness. Q. J. Royal Meteorol. Soc. 104(440):383-392.

The response of a boundary layer wind profile and the surface shear to a large step change in surface roughness is predicted by three calculation methods. The first method, which assumes that local equilibrium exists everywhere, performs less well than the other methods, which employ a transport equation for the shear stress.

322. Wooldridge, Gene L., and Ronan I. Ellis.
1975. Stationarity of mesoscale airflow in mountainous terrain. J. Appl. Meteorol. 14(1):124-128.

The horizontal components of the Lagrangian velocities at levels below mountain ridges are onl wea stationary; the vertical components fit criteria better. Above ridge level, all co velocities exhibit reasonable statio flow.

323. World Meterological Organizatio
1964. Sites for wind-power i Note 63, WMO-No. 156, Switzerland.

Several aspects of local airflow ar ing the sea breeze and valley wind cir over hills and mountains is discussed of air-mass stability and local insolati

324. Yerg, Donald G., and Robert E. D
1979. Statistical analysis of jack pine forest. *In* Fourtee and Forest Meteorol. and

Biometeorol. [sponsored by Am. Meteorol. Soc., Minneapolis, Minn., April 2-6, 1979]. p. 110-111.

An array of Gill-type anemometers mounted 1 meter above ground was located in a jack pine forest. Results indicate that the pattern of wind fluctuations is associated with eddies generated at treetop level and carried downward.

325. Yocke, Mark A., and Mei-Kao Liu.
1977. The development of a three-dimensional wind model for complex terrain. *In* Joint Conf. on Applications of Air Pollution Meteorol [sponsored by Am. Meteorol. Soc. and the Air Pollution Control Assoc., Salt Lake City, Utah, Nov. 29-Dec. 2, 1977]. p. 209-220.

A multilayer, three-dimensional wind model, based upon mass continuity, was developed for predicting wind flow in rugged terrain. For each layer, a Poisson equation is written with wind convergence as a forcing function. Wind data from Arizona were used to test the model.

326. Yoshino, Masatoshi M.
1975. Climate in a small area. 549 p. Univ. Tokyo Press.

Local meteorology is dealt with, including wind in mountainous and forest areas. The influence of topography and temperature on local weather is discussed. Some geomorphological effects due to the influence of local climatology are described.

SUBJECT INDEX

AUTHOR INDEX

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Baughman, Robert G., compiler.
1981. An annotated bibliography of wind velocity literature relating to forest fire behavior studies. USDA For. Serv. Gen. Tech. Rep. INT-119, 28 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Lists and annotates 326 references on wind velocity. Most references relate to wind acting within the local scale of forest fires. Citations are cross-referenced by subject and author.

KEYWORDS: wind velocity, annotated bibliography, wind influence on fire, forest protection